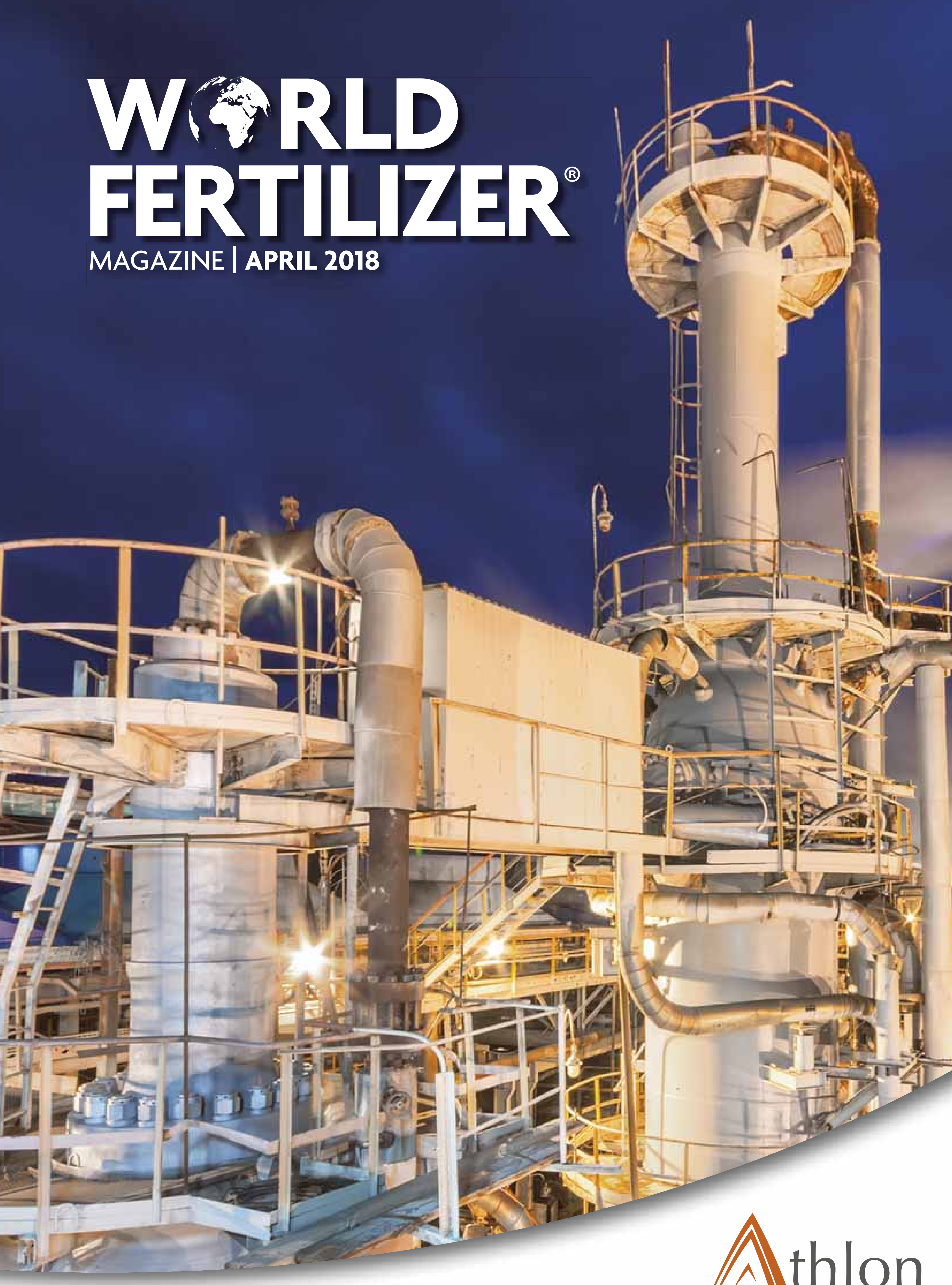
WORLD FERTILIZER®

MAGAZINE | APRIL 2018



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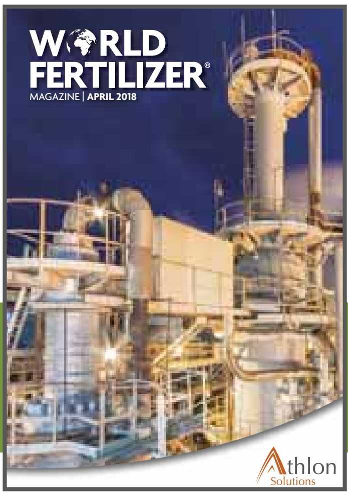

ON THE COVER

Athlon Solutions provides specialty water and process treating solutions to ammonia/fertilizer plants, where large amounts of high pressure steam and high purity water are required. Athlon Solutions has a long and successful track record with: raw water pretreatment, cooling water, boiler feedwater, steam, process condensate, CO_2 removal and UAN corrosion inhibition.

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COMMENT

JAMES LITTLE, MANAGING EDITOR

Cricket, a bat and ball game played between two teams with the aim of scoring more runs than the opposition, has been viewed since Victorian times as the very definition of a gentleman's sport. Indeed 'The Laws of Cricket' actually specify that as well as observing the rules, cricketers must always play within the 'spirit of the game'. In this regard, the captain's role is key in ensuring that the game is not brought into disrepute. The expression 'it's just not cricket' is born of this deep respect above all else for the manner in which the game is played and has come to apply to anything that is deeply untoward, unfair or dishonest. Imagine then the furore that is currently gripping the cricketing world over the Australian team's use of sandpaper to tamper with the ball to their advantage during a recent Test match against South Africa. For cricket mad Australia, the actions of these players including the team captain, have shaken and saddened the nation and as one of the players involved has said, it has left 'a stain on the game we all love'.

This is perhaps a seminal moment for cricket but so too is it for the so-called 'Faang' stocks (Facebook, Amazon, Apple, Netflix and Google) that as this issue went to press have fallen heavily and steadily on the stock market in recent days. Until now, the share prices of the big US tech stocks have been robustly underwritten by widespread confidence in their future prospects. However, if that sentiment has been undermined by recent events at Facebook, this could well be a watershed for the industry.

Facebook has become embroiled in a data breach by Cambridge Analytica, a firm in turn linked to President Trump's 2016 election campaign. It is alleged that the firm harvested the data of 50 million Facebook users, without permission, and then used this information to micro target voters in the US election. That 'team captain' Mark Zuckerberg appeared to handle this situation badly both at the time that the breach occurred and then again when it became public knowledge has put the company's business model in a worrying light. In the same way that the Australian cricket team has brought the integrity of global cricket into sharp focus, questions are being raised about the effects new tighter data regulations could equally have on all of the Faangs and indeed the data analytics industry as a whole – it had already knocked 12% off Facebook's share value and 8% off Google at the time of writing.

Facebook's relationship with the privacy of its users has long been questioned as well as the manner in which it employs surveillance of these users to generate its revenue. It displays adverts depending on user's locations and interests learnt through their browsing history. To date, these activities have been lightly regulated but genuine change is afoot. A new European directive comes into force in May, the General Data Protection Regulation, which will make it more difficult for tech companies to pass on information to third parties for marketing use.

It remains to be seen how effective this new directive will be and the impact it will have first in Europe but potentially beyond as other nations or regions adopt it or something similar. However, what is clear is that the perception of a company or sport can change very quickly. Facebook and Australian cricket were seemingly at the top of their game and their positions unshakable but an awful lot can happen in a very short time...

This month's issue has a regional report on North America and a keynote article on the global sulfuric acid sector. It includes features on process control and storage, as well as a range of other technical topics and will be distributed at both the Syngas 2018 event in Tulsa and the Clearwater Convention in Florida. If you are attending either of these events, we would be delighted to meet you. **WF**

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SUBSCRIPTIONS

World Fertilizer (ISSN No: 2398-4384) is published bimonthly by Palladian Publications Ltd, UK.

World Fertilizer Subscription rates:
Annual subscription: £50 UK including postage £60 overseas (postage airmail)
Two year discounted rate: £80 UK including postage £96 (postage airmail).

Subscription claims:
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WORLDNEWS

INDIA Toyo awarded contract for Indian fertilizer complex

Toyo Engineering Corp. has announced that it has been awarded a contract for the construction of a large scale fertilizer complex in Gorakhpur, Uttar Pradesh state, India.

The complex will be jointly constructed with Toyo Engineering India Private Ltd for Hindustan Urvarak & Rasayan Ltd (HURL). HURL is a fertilizer company jointly established by National Thermal Power Corp. (a state power company in India), Coal India Ltd (a state coal mining company) and Indian Oil Corp. Ltd (a state oil company).

The fertilizer complex will consist of an ammonia plant with a capacity of 2200 tpd, a urea plant with a capacity of 3850 tpd, and a utility supply facility. According to the statement, the ammonia production technology of Kellogg Brown & Root LLC, USA and Toyo's urea synthesis technology, ACES 21®, will be used.

The project is part of a series of national projects promoted under the 'Make in India' slogan introduced by the Indian Government, which aims to achieve full domestic production of chemical fertilizers. With this contract, Toyo has become the first project contractor.

USA Greenfield Nitrogen to build regional ammonia plant through grassroots ownership

Greenfield Nitrogen has announced that it is planning to raise US$120 million towards building the first regional anhydrous ammonia plant through grassroots ownership.

The plant will be located in Garner, Iowa, US, and will cost approximately US$220 million, producing 120 815 tpy of ammonia. On-site storage facilities will enable the company to sell and store up to 66 000 t. Greenfield claims that ownership will give farmers and agricultural retailers access to attractive manufacturers' margins.

The plant will be located in the heart of the corn belt, and will serve the agricultural community within a 100-mile radius. It will produce enough ammonia to meet one-third of the expected shortfall and approximately 1 – 2% of overall nitrogen imports. If the market changes in the future, the plant will be capable of upgrading to other nitrogen products.

As well as meeting local demand for nitrogen fertilizer, Greenfield is also creating a new way for both agricultural retailers and farmers to profit.

Karl Theis, Founder at Greenfield Nitrogen, said: "Greenfield Nitrogen has created a truly distinctive way to allow farmers and agricultural retailers to invest in the same facility so that all investors gain access to manufacturers' margins.

"No other plant has invited participation from both groups."

The plant will use conventional, proven technology to produce nitrogen fertilizer and serve the local market. Greenfield claims that a seed capital round has already raised US$4.7 million. The site is shovel-ready and permits have been granted. Construction is scheduled to commence in 2018, with production expected to commence in 2020.

RUSSIA KBR awarded further work on ACRON ammonia plant in Russia

KBR Inc. has announced that it has been awarded a contract by JSC Dorogobuzh – a subsidiary of JSC ACRON – to provide equipment to revamp its ammonia plant in Dorogobuzh, Smolensk, Russia.

Under the contract, KBR will provide proprietary equipment to enable Dorogobuzh to produce low cost ammonia. Previously, KBR had received a contract from Dorogobuzh to provide its proprietary ammonia technology to increase plant capacity to 2100 metric tpd and to improve efficiency. KBR will utilise its revamp technology KBR Reforming Exchanger System (KRES™) in conjunction with its True Cold Wall Add-on Converter to achieve low project cost for the revamp at this site.

John Derbyshire, KBR President Technology & Consulting, said: "We take immense pride in working with ACRON to revamp its ammonia production facility at Dorogobuzh.

"These recent contracts reinforce the trust of our clients in KBR's proprietary equipment and ammonia technology."

WORLDNEWS

NEWS HIGHLIGHTS

- Blackham Resources and Salt Lake Potash sign MoU
- ICL reveals new five-year targets
- Walmart sees drones as key in the future of farming

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WORLD FERTILIZER® MAGAZINE

UK CF Fertilisers to invest £40 million in Teeside manufacturing complex

A total of £40 million will be invested by CF Fertilisers in its manufacturing complex in Billingham, UK.

The bulk of the money will be spent on two key projects to improve the infrastructure and production capabilities of the site, with development of other facilities and equipment also planned.

CF Billingham Site Manager, Keith Brudenell, said: "The first priority is a £15.75 million project to upgrade and rationalise the Billingham high voltage electricity distribution network including replacement of switchgear on the ammonia plant and upgrading those on the fertilizer production units.

"The new high voltage network will be 'state of the art' with a lifespan in excess of 40 years giving us significant power security for future needs and making for more efficient production."

The second major project is a £15.5 million upgrade to the ammonia reforming plant – designed to extend its life by 20 years.

"This will involve replacement of the steam reforming equipment and gas transmission piping on the high temperature part of the plant and our aim is to complete the upgrade by 2020," said Brudenell.

In addition, CF Fertilisers is investing £8 million to replace a range of equipment in one of its acid plants to improve reliability and meet the growing demand.

Brudenell commented: "All in all, this is a real vote of confidence in the Billingham site and its team and for industrial chemicals on Teesside in general.

"It will allow us to continue the long history of ammonia and fertilizer manufacture at Billingham and make sure we are in the best shape possible to look after the needs of all our employees and customers as we approach our 100 year anniversary in 2023."

News of the investment coincided with exceptional safety statistics released by the company, Brudenell added.

"At both our Billingham and Ince, Cheshire, production facilities we have now recorded 1 million hours of production accident free at each site.

"We are proud to have achieved our best safety record ever in 2017 at Billingham."

EGYPT Fluor awarded FEED contract for Egyptian phosphoric acid production facility

Fluor Corp. has been awarded the front-end engineering design (FEED) contract by Enppi – Egypt's state energy firm – for the offsites and utilities section of the main plant complex and support services for the Waphco phosphoric acid production plant at Abu Tartour, New Valley province, Egypt.

The President of Fluor's Mining & Metals business, Tony Morgan, said: "Our integrated project team is one of the most experienced in the mining and fertilizers industry with the resources, expertise and knowledge to meet the cost, safety and fast-track schedule needs of our client."

Fluor will work with Enppi as an integrated team. It will fast-track the FEED for the plant, which will utilise resources from the Abu Tartour mine to produce merchant-grade phosphoric acid. The project scope includes all process facilities. These include a sulfuric acid plant, utilities with a cogeneration system, storage and other required units. Once the facility is completed, it will produce 500 000 metric tpy of wet process phosphoric acid.

WORLDNEWS

DIARY DATES

SynGas 2018
16 – 18 April 2018
Oklahoma, USA
https://www.syngasassociation.com/

42nd International Phosphate Fertilizer & Sulfuric Acid Technology Conference
08 – 09 June 2018
Florida, USA
http://www.aiche-cf.org/showcontents.php?groupid=12

ACHEMA 2018
11 – 15 June 2018
Frankfurt am Main, Germany
https://www.achema.de/en.html

63rd Annual Safety in Ammonia Plants and Related Facilities Symposium
16 – 20 September 2018
Toronto, Canada
https://www.aiche.org/conferences/annual-safety-ammonia-plants-and-related-facilities-symposium/2018

2018 ANNA Conference
16 – 21 September 2018
Calgary, Canada
http://www.an-na.org/2018-conference/

BULKEX 2018
17 – 18 October 2018
Nottingham, UK
https://bulkex.co.uk

UK Sirius Minerals signs shaft sinking contract with DMC

Sirius Minerals Plc has announced that it has entered into a design and build contract with DMC Mining Services UK Ltd and DMC Mining Services Ltd for the construction of four shafts required for its polyhalite project in North Yorkshire, UK.

DMC Mining Services UK Ltd and DMC Mining Services Ltd are both subsidiaries of KGHM Polska Miedz SA. In the statement, Sirius claims that it has been in extended discussions with AMC UK Ltd in respect of finalising the shaft sinking contract following the 'notice of award' in July last year, which anticipated the signing of a finalised contract shortly after. Because of protracted discussions with AMC regarding commercial arrangements, Sirius opted to engage with DMC and other shaft sinking companies in parallel to consider alternatives.

Sirius claims that, through this process, it has become clear that DMC is a strong partner, and will bring technical opportunities and a commercial partnership that can unlock potential savings in the construction schedule. Sirius has therefore entered into a design and build contract with DMC and has terminated ongoing arrangements it had for the shafts with AMC.

The Managing Director and CEO of Sirius, Chris Fraser, said: "Sirius continually seeks opportunities to use innovations and a commercial approach to accelerate development and unlock value. DMC has proven, world leading experience using Herrenknecht SBR technology on deep shafts and represents a strong partner, commercially aligned to our success. We are confident that they can deliver the North Yorkshire polyhalite project shafts significantly earlier than all previous expectations and we look forward to working with the team."

The Managing Director of DMC, Graham Buttenshaw, added: "We are excited to be partnering with Sirius on this world class project and are confident of leveraging our leading technology and experience to accelerate development of the mine and enable Sirius to bring its sustainable multi-nutrient fertilizers to the market earlier than previously planned."

CANADA Gensource enters potash offtake MoU

Gensource Potash Corp. has announced that it has entered into a non-binding memorandum of understanding (MoU) with a long-time leader in the North American agriculture industry.

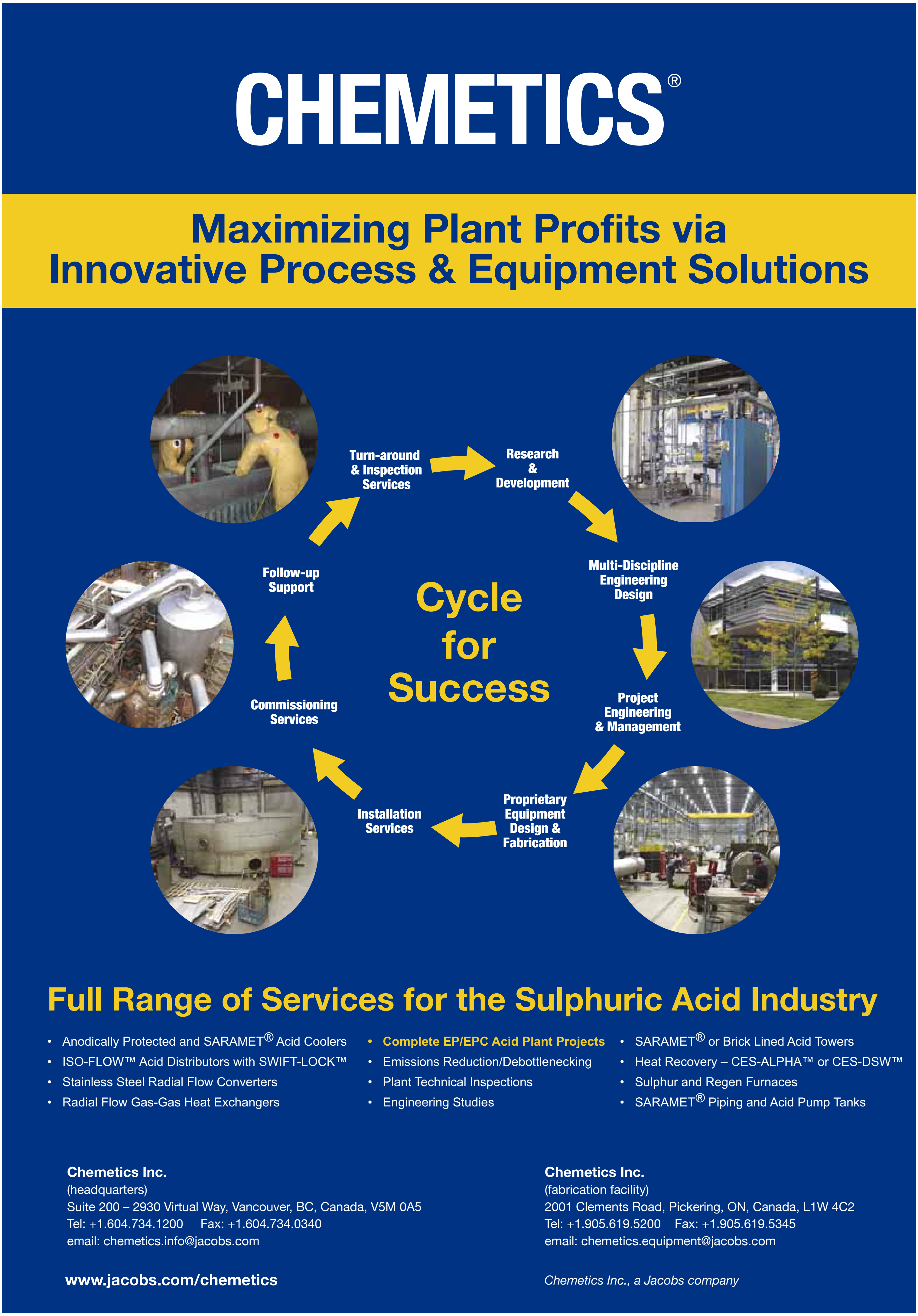
The MoU formalises the offtaker's interest in potentially purchasing 100% of the planned 250 000 tpy production from one of Gensource's small scale potash facilities, which will be located in its Vanguard area in central Saskatchewan, Canada.

The MoU also proposes certain terms that will become key components of a definitive offtake agreement. The definitive agreement may create a relationship that will establish the vertical integration structure that Gensource holds as a key pillar in its business plan – a structure that will supply potash from Gensource's production facility in Saskatchewan directly to end-users. Whilst Gensource will provide the potash, the offtaker will utilise its transportation and logistics capabilities. Combined, both parties will create a complete and independent supply chain.

Highlights of the MoU include: the potential commitment to purchase 100% of the production from one 250 000 tpy module; an industry standard pricing structure for delivery of product to the US market; and employment of the offtaker's existing transportation and logistics infrastructure to move product.

The MoU contemplates that the parties complete the definitive agreement by the end of April 2018, and efforts in that respect have already commenced.

Concurrently with the completion of the definitive offtake agreement, Gensource will define and assemble the required finance package that will support construction of the project on the currently planned schedule. Construction is scheduled to start later this year, with first production in 18 – 22 months.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North America Under the Microscope

Economists tell us that, when a commodity sector enters a downcycle and prices remain low for several years, producers generally correct the situation by closing older, less profitable sources, curtailing investment in new capacity and consolidating firms in order to generate synergies that reduce overhead.

The fertilizer sector has been in an extended downcycle for several years now, and participants are working to rectify the situation in the prescribed manner. In North America, their actions are being dictated by a number of factors reflecting both short-term supply and demand, and long-term investment decisions.

Ammonia

North America has 21.7 million tpy of ammonia capacity. In Canada, most of the 5.4 million tpy capacity is located in the western provinces, close to natural gas supplies and farms. Nutrien and CF dominate the Canadian sector. In the US, 16.3 million tpy of capacity is spread between Texas and Louisiana (near inexpensive natural gas), and prominent corn and wheat growing states (Iowa, Illinois). Major US companies include CF, Koch and LSB Industries. Trinidad and Tobago also has 2 million tpy of capacity, operated by Nutrien.

North America has a total of 15.7 million tpy urea capacity. Most (approximately 11.6 million tpy) is located in the US; CF Industries, Koch and Nutrien are major producers. Canada has 4.1 million tpy capacity; Nutrien, CF and Yara are major producers. Trinidad and Tobago has 700 000 tpy capacity.

In 2017, new nitrogen capacity entered production at Agrium's Borger, Texas, plant, Koch's Nitrogen Enid, Oklahoma, facility, and Iowa Fertilizer's Wever, Iowa, plant. This largely completes the current cycle of capacity expansion in North America that was initiated by higher commodity prices earlier in the decade.

International capacity growth is also beginning to wane. In its 2017 Investor's Report, CF Industries noted that the net growth in world urea capacity was 16.6 million t in 2015, 4.2 million t in 2016, and 4.2 million t in 2017. Projections for 2018 are a net urea gain of 2.0 million t, and 2.8 million t in 2019. By 2020, net expansion slows to 500 000 t. Even at modest 2% growth, global demand begins to exceed new supply by 2019.

CF noted that total agricultural nitrogen demand in the US and Canada stood at 15.6 million t in 2017, and growth is expected to be relatively static over the next several years.

CF also noted that total North American nitrogen fertilizer imports had stood at 9 million metric t in 2015; that began to fall

Gordon Cope, *World Fertilizer* contributing editor, provides an overview of the current North American fertilizer market.

in 2016, and averaged slightly more than 7 million t in 2017, reflecting new capacity in North America displacing imports.

PotashCorp reported that the convergence of supply and demand late in 2017 had a positive impact on urea prices; ammonia and UAN prices also strengthened, although the new expansions muted their rally.

Analysts are pointing to the development of a strategic nitrogen reserve in China. In early 2018, Nutrien CEO Chuck Magro spoke at the CIBC Investors' Conference in Whistler, British Columbia, Canada, and addressed the issue. He noted that the Chinese government was not comfortable with high domestic urea prices, and may want to bring prices down by creating a strategic reserve. "This will have a profound impact on Chinese exports," he noted. "It will be good for the US market, and good for nitrogen through 2018."

Potash

North America has 36 million tpy of potash capacity. Most of this, over 35 million tpy, is located in the Canadian province of Saskatchewan. Nutrien is the dominant producer, with 22.6 million tpy capacity; Mosaic Co. has 12.6 million tpy of capacity, also located in Saskatchewan. In the US, Intrepid operates four smaller mines in Utah and New Mexico, with a total capacity of 735 000 tpy.

Canada is a major exporter of potash, sending 10.6 million t in 2016 to the US, Brazil and China. The US is the third largest exporter of phosphate fertilizers, sending 3.7 million tpy to Brazil, Canada and India.

High cost production has been rationalised. In 2016, PotashCorp closed a mine in New Brunswick and cut more than 500 jobs at its Cory mine, west of Saskatoon. That same year, Minnesota-based Mosaic Co. laid off 330 workers from its potash mine in Colonsay, located 65 km southeast of Saskatoon. In late 2017, PotashCorp idled two mines for several months, reducing its annual production quota by 1 million t.

In mid-2017, K+S Bethune mine, located in Saskatchewan, came online. The CAN$4.1 billion facility, initiated in 2012 when commodity prices were higher, can produce up to 2 million tpy of low cost potash. According to Bernstein Research, a consultancy, the mine functioned at 25% of nameplate capacity in 2H17. Although teething problems are expected with any new facility, it may also be a reflection of current market conditions and producer discipline.

Also in mid-2017, PotashCorp announced the successful expansion of its Rocanville underground mine, located 230 km east of Regina. The CAN$3 billion project took eight years to complete, and added 3.5 million t to the 3 million tpy nameplate capacity. In an earlier press release, the company stated its intention to run the mine at 5 million tpy.

In late 2017, PotashCorp CEO Jochen Tilk (now Executive Chair of Nutrien's board of directors) summarised PotashCorp's response to the low commodity cycle. "We reduced our cost about 50% over time by bringing our cash cost down consistently, and part of that was the reduction and the suspension of high cost operation, the other part was the support in building up capacity of our lowest cost operations."

Capital investments in new capacity have also been under scrutiny. BHP began exploring the Jansen prospect, located approximately 140 km east of Saskatoon, in the mid-2000s. So far, the company has spent almost US$4 billion on the project, primarily on the massive shafts that descend to the deposit. The total cost is estimated to be approximately US$14 billion.

In mid-2017, BHP announced that it was delaying any final investment decision (FID). "Once we have completed the shafts, we will have totally de-risked the project," CEO Andrew Mackenzie told reporters and analysts on a conference call. "We will have dealt with all the difficult parts of it. And, we will only be three years away from first potash when we think it's appropriate to make the right counter-cyclical investment."

BHP predicts that potash demand will outstrip supply by the mid-2020s, and that the project will eventually be viable. In the meantime, they are exploring options to slow development, bring in new partners, or sell the asset.

Saskatchewan's Ministry of Environment has given approval to Western Potash's Milestone Phase I project. The company has secured an offtake agreement with a Chinese buyer, and is seeking further contracts in North America. The project will use selective solution mining, which has lower CAPEX and OPEX costs than conventional solution mining.

In late 2017, PotashCorp, a major exporter, reported that potash prices improved throughout 2017 due to strong demand and affordability. Shipments to China and India accelerated in late 2017, and deliveries to Brazil and other Latin America countries continued at a record pace. The company expects to see strong demand continue through 2018.

Bernstein Research noted that growth in potash demand was approximately 4% in 2017, or 2.5 million t, and predicts it will be approximately 2.5% in 2018, equal to 1.6 million t. The tightening of the market will allow prices to continue to rise, with a year-end target for Brazilian granular MOP at US$330/t.

"We expected a soft year in potash in 2017, but demand was strong," noted Magro, at the CIBC Investors' Conference in Whistler. "We expect global demand to grow 2 million t in 2018, about 3% growth."

Magro attributes part of the demand to the conversion of pastureland to agriculture in Brazil, but also to developments in India and China. He noted that the two governments have mandated soil sampling, and the lab results have indicated significant stress, and that the need to replenish is acute. "Chinese (domestic) production may have peaked, and there will be a demand for more imported potash. We are bullish for the entire year."

Phosphate

North America has 8.8 million tpy phosphoric acid plant capacity. The US has the majority, approximately 8.5 million tpy, mostly located in Florida. Nutrien, JR Simplot and Mosaic are major producers. Nutrien has the sole Canadian production – a 345 000 tpy plant located in Alberta.

The relative health of the global phosphate market is largely governed by events in China. The country's soils are deficient in phosphate. Several decades ago, the central government supported the development of domestic supplies. Production of phosphoric acid increased from approximately 3 million t in 2000 to 18 million t in 2016, representing approximately 45% of global production. As a result, China became a significant exporter.

Recently, the government, in an effort to improve the environment, has been ordering the closure of older, polluting facilities. According to China Phosphate Industry Association, approximately 3 million t of P_2O_5 capacity will be closed permanently during 2015 – 2020.

In late 2017, PotashCorp noted that phosphate fertilizer was experiencing moderate appreciation due to stronger demand from India and weather-related supply outages (see hurricane sidebar). Exports from China will continue to place pressure through 2018, however.

Fertilizer consumption

According to Nutrien, the world is expected to consume approximately 191 million t of NPK fertilizer during the 2017 – 2018 growing season. Over half the world's fertilizer is consumed in East Asia and South Asia – approximately 103 million t. North America consumes 13%, or 25 million t. Of that, the US consumes 20.4 million t, and Canada 4.6 million t.

The World Bank notes that acreage under cereal production exceeds 720 million ha. globally. North America has 82 million ha. (Canada has 14 million ha., and the US 68 million ha.), or 11.4% of the global total. The market for fertilizer in North America is relatively mature. In the US, 97% of corn under cultivation receives an average of 241 lb/acre of NPK fertilizers.

USDA outlook

In the US, the planted acreage for eight major crops (corn, soybeans, wheat, cotton, sorghum, rice, barley and oats) has fluctuated around the 250 million acres mark over recent years, but the USDA projects that it will decline to 245 million acres over the next decade, primarily due to decreased corn planting.

Canada produced 12.3 million t of corn, or almost 500 million bushels. The US corn sector is much larger. The US consumes 5 billion bushels of corn for human food and animal feed and industrial uses. It also converts 5 billion bushels into fuel ethanol, and exports slightly less than 2 billion bushels.

The USDA believes that human and feedlot consumption is expected to rise over the next decade to 6 billion bushels, fuel ethanol consumption to decline to slightly less than 5 billion bushels, and exports are expected to rise above 2 billion bushels per year as developing countries become more affluent and increase their meat consumption.

The US consumes 1.2 billion bushels of wheat every year and exports an additional 1 billion bushels. Wheat production is expected to remain constant, although acreage will decrease. In 2017, Canada produced over 25 million t of wheat (over 900 million bushels), exporting approximately 15 million t (550 million bushels).

The USDA predicts that the drop in US farm-level prices due to overproduction has now bottomed out, and the nominal bushel prices for corn, wheat and soy in 2017 (US$3.30, US$3.70 and US$9.20, respectively) are expected to rise over the next decade to US$3.70, US$5 and US$9.50.

Mergers and acquisitions

Beginning in January, 2018, Agrium and PotashCorp began joint operations under the name of Nutrien. The newly-amalgamated company has the nameplate capacity to produce 22.6 million tpy of potash, 7 million tpy of ammonia, 4 million tpy of urea and 2.4 million tpy of phosphate. The amounts represent 63% of North American capacity for potash, 22% for ammonia, 21% for urea, and 25% for phosphate. Nutrien is also the dominant retailer in North America, with 1200 rural outlets.

Hurricane impact

The US Gulf Coast (USGC) region is home to major oil and gas, petrochemical and fertilizer facilities. When category 4 Hurricane Harvey made landfall in the region of Corpus Christi, Texas, on 27 August 2017, plants had already suspended operations and evacuated personnel. Although heavy winds and 50 in. of rain caused disruptions, most plants were up and running within two weeks.

Less than two weeks later, however, the USGC was hit by Hurricane Irma. After devastating many Caribbean islands, the category 5 hurricane made landfall in the Florida Keys. Working its way up the gulf shore, it caused 90 fatalities and billions of dollars in damages.

Mosaic has four phosphate mining and fertilizer production facilities in Central Florida, including Bartow, New Wales, Tampa and Plant City, for a total phosphoric acid nameplate capacity of 4.5 million tpy. The company suspended operations during the hurricane, and subsequent evaluation after it had passed determined that a Bartow warehouse and products had been damaged. Fortunately, no staff were injured or environmental damage occurred.

The temporary disruption to a major phosphate supply region had a financial impact on the commodity, however. Barge prices for DAP in New Orleans rose 5% to US$336/short t in the three weeks after Irma landed. Mosaic itself later issued a statement citing a loss of US$26 million to its phosphate operations due to the hurricane.

The future

The majority of construction of nitrogen capacity in North America is complete. The new low cost capacity, located near demand, will continue to displace imports. Prices for corn, wheat and soy are expected to rise slowly over the next several years as international demand increases. Higher farm incomes equate with greater fertilizer consumption, bolstering nitrogen prices.

International sources of NPK will continue to affect the North American market. Phosphate exports from China, for instance, will maintain market pressure on North American operators. Production at facilities in the US and Canada will remain well below nameplate capacity.

Recent efforts in North America to consolidate production, close high cost facilities and engage in market discipline are beginning to have a modest positive effect on prices. The relative lack of capital investment over the next several years is expected to allow growth in demand to balance with supply, strengthening the fertilizer market in the next decade. "Market fundamentals are improving this year, and we think the next few years, as well," says Magro. WF

Peter Harrisson, CRU Group, UK, provides a review of the global sulfur market and looks ahead to 2018 and beyond.

sulfur: what goes up must come down

The global sulfur market is inherently volatile due to the involuntary nature of production and the remote locations of marginal supply. The length of the supply chain makes it difficult for stockholders to be responsive to short-term disruption in supply or demand, and this is a major factor in driving volatility even with only typical seasonal movements in demand. Since 2014, sulfur prices have trended downwards as the global market has moved into oversupply (Figure 1). In 2014, the global market is estimated to have been in a deficit of 1.0 million t, which moved to a deficit of only 0.1 million t in 2015. In 2016, growth in sulfur production in the Middle East and commonwealth of independent states (CIS) pushed the market to a surplus of 0.8 million t, which pulled the market into a lower-priced environment. From 2Q16 to 2Q17, prices were locked in a range of US$65/t – US$90/t at FOB, which reflects the cost of bringing marginal tonnes to the market.

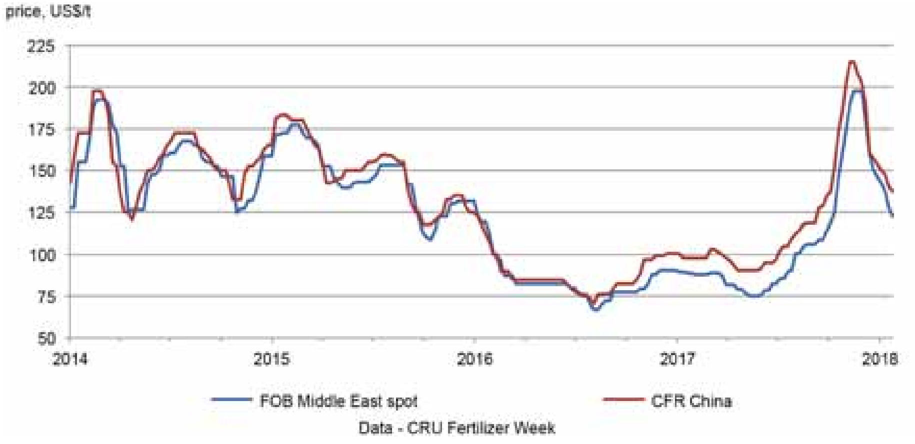


Figure 1. Sulfur price history.

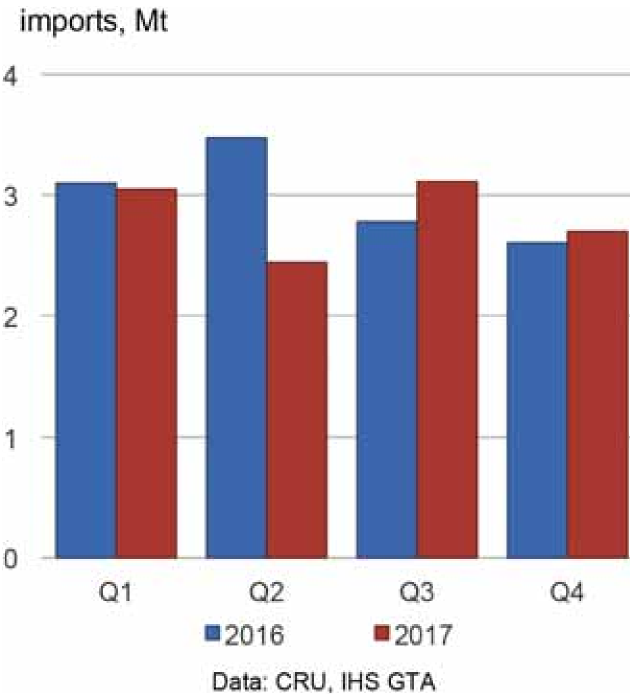


Figure 2. China imports fall in 1H17 and rebound in 2H17.

In 1H17, the market remained oversupplied with prices following typical seasonal trends. In 2H17, production issues in major supply origins (Canada, CIS) tightened short-term availability at ports, which triggered surging prices as the unexpectedly constrained supply was met with greater-than-expected seasonal demand. The dramatic increase in prices caused many to question whether the global market had shifted away from oversupply and whether strong demand could maintain a new, higher level of prices into 2018.

Prices rally in 2H17 – what were the drivers?

During 2H17, sulfur prices at CFR China jumped from a low of US$85/t in July to over US$225/t in November. The rally in sulfur prices in 2H17 took the market by surprise as tight supply coincided with a seasonal increase in demand. The key drivers of the change in the market were an increase in Chinese demand, but also tight global supply with lower-than-expected production in Canada, the US and China.

China had low levels of sulfur imports in 1H17, with consumers relying on stock drawdown to cover demand. In 3Q17, stocks were low, DAP prices remained strong, and sulfur demand increased. China returned to an international market that did not have sufficient supply to meet demand. The price rally was based on short-term physical market tightness, and the market peaked in early November 2017, with prices falling back sharply as supply recovered and demand subsided.

Chinese import volumes and port stocks

China accounts for approximately one-third of annual imports in the global sulfur market. With such a significant share of global trade, changes in consumption or buying patterns in China can have a significant impact on the market. China is also a market that holds a stockpile of sulfur at ports, which can be utilised to buffer the local market against short-term supply disruption.

China typically has strong purchasing in the mid-second quarter, late third quarter and late fourth quarter to coincide with local consumption seasons. In 2017, China reduced its sulfur imports in 2Q17 as prices declined in the global market. In 1H17, Chinese imports totalled only 5.5 million t, down by 17% y/y. During 1H17, port stocks in China declined from 1.6 million t to 1.0 million t. The lack of purchases in 1H17 caused a stronger-than-expected rebound in import demand in 3Q17. At that point, Chinese port stocks were at low levels and did not offer an opportunity to supplement supply in the market.

The impact that China had in 2017 is tied to the timing of its purchases and not the absolute volume. China cut total imports for 2017 by 6% y/y, but the disparity between quarterly import demand levels drove prices up. The delayed purchasing in China was tied to uncertainty on the direction of prices in the international phosphate sector. At the point when Chinese buyers had formed a view, the sulfur raw material they needed was no longer waiting for them to buy.

Supply disruption at major sulfur export points

China was the catalyst that triggered the run-up in prices, but it was disruption to supply that provided support for the further increases in 2H17. North America and the CIS account for 35% of global trade, with much of the production in these regions in geographically isolated locations.

In North America, Canada suffered production issues in 2017, with supply lost in the Alberta Oil sands in the second and third quarters, and low production rates in the British Columbia gas sector throughout the year. US Gulf refiners also cut sulfur production in 3Q17 following Hurricane Harvey, which accentuated the tightness in supply availability.

In the CIS, Russian export availability was cut due to increased local demand for sulfur as Russian fertilizer producers significantly increased operating rates. Sulfur from Kashagan in Kazakhstan was in production, but was unable to access the international market due to logistics issues.

The Middle East also had lower export availability due to the shutdown of some capacity in Kuwait in the second

quarter and minor technical issues across the region throughout the third quarter.

Japan and South Korea also reduced molten sulfur exports in 2017, with combined sales down by approximately 10% on total exports of 2.6 million t.

It was not only the scale of disruption to supply, but also the timing that fuelled the run-up in global prices. Much of the supply tightness was driven by unexpected issues which triggered longer-than-typical curtailment of production.

What will influence sulfur prices in 2018?

Towards the end of 2017, sulfur prices declined. This represented the point at which short-run influences were replaced by the fundamental trends in the market. The global sulfur market was oversupplied in 2017, but this annual surplus was split between oversupply in 1H17 and deficit in 2H17. China reduced total import demand in 2017, but this reduction was weighted towards a large cut in 1H17 and flatter demand in 2H17.

Figure 3. Chinese sulfur port stocks consumed to support weak 1H17 imports.

In 2018, the fundamental trend of oversupply is expected to take hold again. The global surplus is expected to increase as new production capacity is brought into the market in Kuwait (0.5 million t) and Vietnam (0.3 million t), along with a recovery in production rates in regions which faced production issues in 2017 (Canada, the US). There will also be the release of production from Kashagan onto the international market with stock drawdown expected to supplement sales of new production from the operation.

Global sulfur demand performed strongly in 2017 with increased consumption in Morocco, Russia, Saudi Arabia and Southeast Asia. However, there is not expected to be a repeat of this exceptional growth in 2018, with several markets, most notably China, forecast to cut demand. Growth in consumption is expected to be more focussed in Morocco, Saudi Arabia and Brazil, where big buyers hold significant negotiating influence.

The rate of production growth in 2018 is slower than in recent years, but the difference, in terms of market impact, will be how this growth rate compares with increases in demand and trade. In 2015, very strong supply growth coincided with increases in import demand in new markets along with some of the new production being in isolated geographical locations. This prevented a weakening of global prices.

In contrast, since 2016, growth in the traded market has slowed, which has reflected a redistribution of trade flows as opposed to an expansion in the market. Competition for a share of existing markets has driven the downwards trend in prices. In 2018, supply growth is expected to exceed the growth in demand, with a limited increase in global trade. This will be reflected by a decline in imports in China and India and demand growth in Morocco and Saudi Arabia.

The other major factor that will impact the sulfur market is demand and pricing in the phosphate sector. Phosphate prices increased in response to higher sulfur levels in 2H17, which helped to further support the price rally. However, in 2018, the increase in capacity in Morocco and Saudi Arabia is expected to negatively impact prices. Another factor is that the strong sulfur demand in 2017 was caused by higher than expected levels of phosphate purchases. For 2018, it is expected that some of these purchases are yet to be consumed, leading to weaker fertilizer demand for the year.

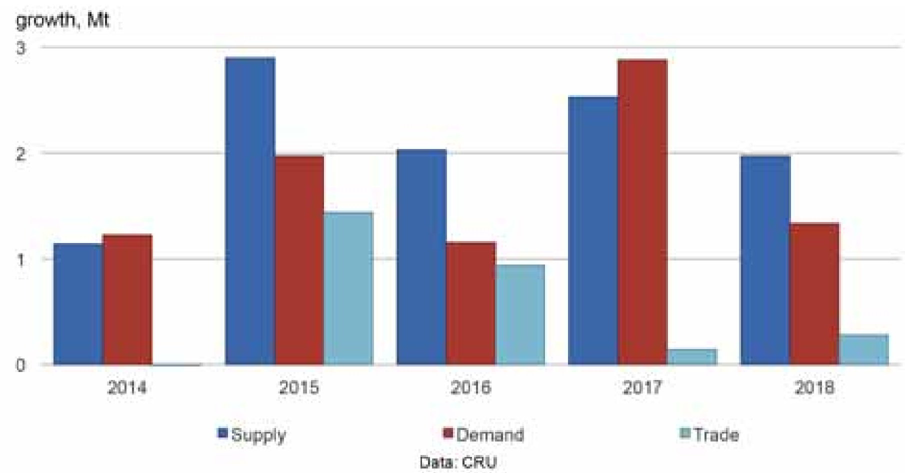


Figure 4. Supply growth exceeds demand in 2018 with limited traded market expansion.

The market is expected to move back to a similar environment as in 1H17. Prices are forecast to move down in response to growing supply and weakening downstream market prices.

However, the trend into 2018 is not expected to last forever. Supply growth rates are slowing while demand growth is accelerating. It is expected that the correction back towards a balanced market will start from 2019, with deficits emerging from 2020. The response to tighter market conditions will again require consumers to compete to attract supply out of geographically isolated and costly regions of the world. WF

Creative MDEA Reclamation Avoids Downtime

Richard Pearson, Athlon Solutions, USA, shows how an ammonia plant reclaimed 30 000 US gal. of MDEA without a costly and unscheduled turnaround.

There is a lot at stake. If not corrected, contaminated methyl-di-ethanol-amine (MDEA) will impact a plant's production, product quality, asset integrity and bottom line by millions of dollars.

MDEA is a tertiary amine used in ammonia plants to remove carbon dioxide (CO_2) from the synthesis gas stream. The colourless, ammonia-odour liquid is an industrial process treatment staple not only in the ammonia and fertilizer manufacturing world, but also in the chemical, refining and petrochemical industries.

When MDEA is contaminated, plant operations are often forced to shut down or expedite a scheduled turnaround to reclaim or replace the MDEA and correct the underlying issue. If not, excessive acid gases in the process gas stream and lean MDEA can cause corrosion and impact production. The contaminants can also form deposits causing mechanical obstructions in the absorber and stripper trays restricting amine system circulation rates.

During ammonia production, CO_2 generated in the reformer must be removed from the process gas stream. System contamination can reduce efficiency in absorption and stripping processes. Poor absorption of CO_2 stresses the methanator catalyst and reduces production rates. Poor stripping of the CO_2 causes corrosion in the reboilers on the stripper towers.

Athlon Solutions' experience with a major global ammonia-UAN manufacturer in the US presents the challenges, solutions and benefits that have become a successful blueprint for the industrial water and process company in similar engagements. The result – increased production reliability and equipment preservation.

MDEA contamination

A leading ammonia manufacturer's Midwest plant had a major issue.

The plant has a long history of manufacturing quality anhydrous ammonia and UAN fertilizers. In fact, it is an important part of the Midwest's extensive plant and terminal system serving the US agriculture industry. So, when there is a hiccup in operations and the supply chain, it is noticed. A solution needs to be fast – not only for the company's operations, but also for the welfare of the supply chain.

Routine quarterly analysis performed by Athlon Solutions' lab showed unusually high levels of chloride (approximately 600 ppm) and sulfate (approximately 1250 ppm) ions in the MDEA circulating in the plant's absorber/stripper system. Athlon Solutions advised the local plant team that a problem existed after the detailed analysis disclosed a previously undetected issue. The MDEA was contaminated.

Chloride levels in the MDEA had increased dramatically and signs of damaging corrosion and deposition were beginning to show on the plant's assets.

The plant's operations team had already thought of options to correct it. The leading one required an unplanned shutdown to replace the existing volume (30 000 US gal. or approximately 114 000 litres) of MDEA with a new solution.

Doing this would cost the company millions of dollars factoring in the recovery of the contaminated MDEA and the manufacturing downtime.

The plant was also not authorised to handle the highly regulated piperazine, which is a crucial chemistry blended into the MDEA solution. Shipping and storage costs would be incurred to manage the blending of piperazine into the clean concentrate.

The addition of piperazine is essential. MDEA reacts rapidly with some gases, such as H_2S, to aid in scrubbing the acid gas. Due to no direct reaction with carbamates, MDEA reacts very slowly with CO_2.

To increase MDEA's CO_2 reaction and removal rate, small concentrations of piperazine (a cyclic, secondary diamine) are added. This combination is known as activated MDEA (a-MDEA). It has been the preferred choice of plants for more than 25 years.

Benefits of MDEA/piperazine

MDEA reacts slowly with CO_2 on its own. When piperazine is added, it becomes a-MDEA. The CO_2 reaction and removal rate increases. This process was patented more than 25 years ago. The patent has expired. Now, a-MDEA is the choice of many new ammonia and fertilizer plants and older ones that have invested equipment to use a-MDEA.

The benefits of include the following:

- Higher capacity for reaction with CO_2 than other absorbents such as MEA/DEA.
- Low heat of absorption allows cooler absorber temperatures. This favours CO_2 absorption.
- Low heat of absorption means low heat of desorption requiring lower energy for regeneration, desorption of CO_2.
- More concentrated solutions with low corrosion further increase capacity for CO_2 removal.

Benefits to the owner/operator to overcome the higher cost relative to MEA/DEA include reduced capital investment, lower operating costs and improved removal of CO_2 as a result of the following:

- Lower equipment size because of its greater capacity for CO_2 removal.
- Less energy for regeneration (i.e. reboiler steam requirements).
- Less corrosive in use even at higher use concentrations than MEA/DEA.

Corrosion is always a concern

The concern for corrosion was high. Elevated corrosion rates (typical for many amine plants) and stress-corrosion cracking of stainless steel are usually attributed to high chloride levels. This also creates serious safety concerns.

High corrosion leads to costly repairs, potential environmental implications and production loss.

Corrosion is prevalent in amine systems. The result of a survey taken by the National Association of Corrosion Engineers (NACE) indicates that 60% of 24 amine systems surveyed experience stress-corrosion cracking in the amine absorbers. A similar survey by The Japanese Petroleum Institute (JPI) reported 72% occurrence of stress corrosion cracking at amine gas treating facilities. Carbon steel corrosion is often attributed to the amine contaminants that cannot be stripped and thereby accumulate in the amine solution.

The issues were stacking up for the ammonia plant. There was a sense of urgency for a solution, especially since the plant's primary water and process treatment vendor was not able to help and the scheduled turnaround was nearly a year out.

Figure 1. Reduced chloride levels after changeouts.

Table 1. MDEA analysis of the key areas of concern after the final batch changeout

Element	Starting MDEA	After final changeout
Chlorides by IC	605 ppm	97 ppm
Sodium by ICP	915 ppm	222 ppm
Sulfate by IC	1233 ppm	152 ppm
Glycolate by IC	29 ppm	45 ppm
Acetate by IC	3239 ppm	985 ppm
Formate by IC	1953 ppm	744 ppm
Propionate by IC	61 ppm	27 ppm
Oxalate by IC	99 ppm	16 ppm

To clean or replace?

The first step was to analyse the data. This allowed the team to determine the scope of the problem and establish if the cause was mechanical, operational or chemical.

As noted earlier, the plant's operations team had already been notified by Athlon Solutions that the chloride and sulfate ion levels were high in the MDEA. However, an underlying cause was escaping detection. The plant team could verify that a cooling water system leak (a potential cause) was not the source and the contaminant levels did not seem to be increasing. After much investigation, it was determined that snow melt had entered the MDEA system through the sumps. The packed and hardened snow had accumulated large deposits of de-icing salt and other contaminants.

The analysis of the contaminated MDEA using inductively coupled plasma (ICP) spectroscopy, ion chromatography (IC), titration and foam testing confirmed the high chloride and sulfate levels, but it also showed several other areas of concern, including issues with sodium. Finally, elevated organic acid levels were indicating oxygen ingress into the system (also from the sumps).

The elevated chlorides were the biggest concern. They were going to drive corrosion and stress-corrosion cracking of stainless steel. This would result in costly repairs and downtime if not corrected.

The big question facing the plant and the treatment team was whether 30 000 US gal. of MDEA should be cleaned or replaced. Either way, it was a daunting task. Although, keeping the plant operational was the most attractive option as the production losses would amount to several million dollars.

After reviewing the data and discussing the options with the plant's leadership, the best option was to reclaim the MDEA. Doing so would keep the plant running, avoid the purchase of new MDEA and all the costs associated with an unscheduled turnaround.

Athlon Solutions and plant operations decided to reclaim the MDEA through a series of batch changeouts (approximately 5000 US gal. each). Having the analysis of the contaminated MDEA would allow the team to track the recovery between batches and determine how many batch changeouts would be needed.

As for blending the piperazine into the MDEA, that could be handled by Athlon Solutions and its partners. Athlon Solutions would supply its MDEA product, Prosorb, which is premixed with piperazine. It could be shipped in concentrated amounts to its reclamation partner to custom blend the returned a-MDEA to meet the specifications required in the customer's online amine system.

Commitment to production reliability and equipment preservation

After 10 months and nine changeout batches, the plant's MDEA and acid gas removal levels returned to optimum operational standards.

There was no unplanned turnaround and no loss of production for the plant. The investment in the changeout volume and the supporting services was much less than the millions of dollars the plant would have lost with downtime.

An unscheduled turnaround was avoided due to an experienced operations and treatment team identifying a problem during routine analysis. They worked together to understand options and the associated impacts. Moreover, it was an example of all parties understanding that without an experienced water and process treatment program and team to implement, maintain and optimise it, a plant's production and equipment are at great risk.

Effective water and process treating is imperative to successful ammonia and fertilizer plant operations. WF

Reducing Costs With Modern Fans

Christian Menke, Ventilatorenfabrik Oelde GmbH, Germany, explains how modern fan technology can reduce the operating costs of fertilizer plants.

The production of fertilizers is not only complex, but also energy-intensive. It is a matter of interest, therefore, that energy savings of sometimes more than 25% can be achieved with high efficiency centrifugal fans and their auxiliary equipment, which are required for the manufacture of fertilizers.

Demands made on fans during fertilizer production

High demands are placed on process fans used in plants where basic chemical materials, such as ammonia, or fertilizers, such as urea, are produced. They must be efficient, safe, long-lasting, robust and resistant to outside influences, such as the aggressive ambient conditions present in chemical plants, or changeable climatic conditions.

API Standard 560 clearly defines that a fan, including its auxiliaries, must have a minimum service life of 20 years and guarantee continuous operation for three years without interruption (API 560, § E.3.1.1). This underlines the high availability demanded from these fans, which are a key component in every plant. They handle air for cooling and drying the product, convey clean air from wet scrubbers into stacks, and are part of the dust collection systems.

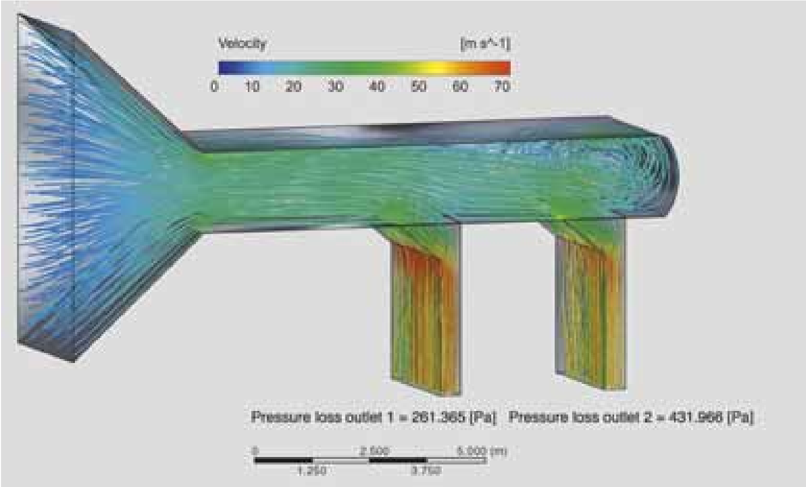


Figure 1. Original design.

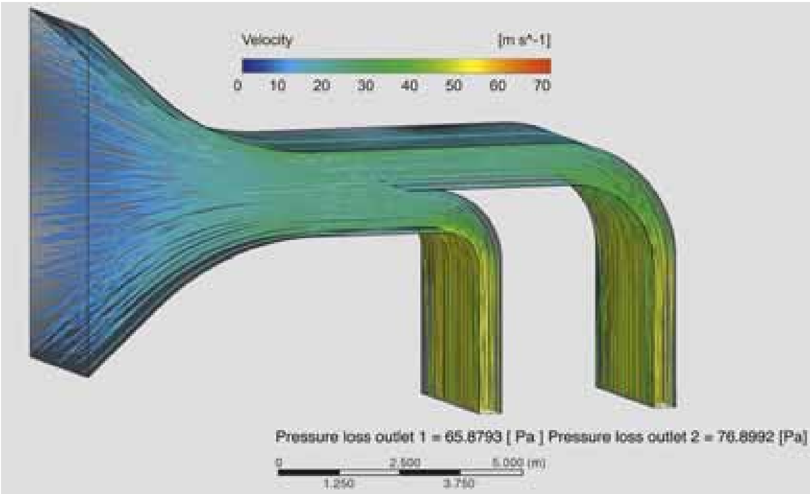


Figure 2. Optimised design.

Whenever a fan fails, the production process usually stops. In a large plant for urea manufacture, a single day of stoppage caused by production downtime results in a loss of several hundred thousand euros.

Efficient fans – work horses with digital precision

At a glance, a fan may look the same as it did 50 years ago. The basic principle is, of course, the same. However, shape, geometry and angling of the impeller blades are nowadays aerodynamically optimised using modern computer simulation. This improves efficiency while simultaneously reducing both the tendency to caking and wear from any abrasive particles present in the gas handled.

In a similar fashion, the fan casing must be perfectly adapted to the rotor assembly. An optimised interaction of impeller and casing alone permits higher efficiency.

Improved auxiliaries – objective without loss

In general, the power consumption of a fan is determined by the operating parameters: volume flow, pressure increase, gas temperature and density. While volume flow and temperature are almost always fixed process parameters, the pressure generated is, however, only partially required for the process itself.

A not inconsiderable portion of the pressure increase produced by the fan is needed to compensate for the pressure losses caused by components situated on the fan inlet or outlet, such as filters, silencers, control equipment and connecting ducts. In practice, the influence of the inlet and outlet situation is often neglected or simply accepted, although it is here especially that there may be a large energy saving potential.

An ideally designed connecting duct contributes greatly to lowering pressure losses and, therefore, investment costs. It may be possible to use a smaller fan with a lower motor output.

An ancillary effect of the reduced fan power consumption is a lower energy requirement. The plant operator reduces energy costs and the negative environmental impact is lessened.

Basically, when designing a duct, the following must be taken into consideration: as few bends and turns as possible; avoidance of irregular reductions; and where there is a smooth widening, ensure the angles are ideal. Since, in practice, bends and turns cannot be avoided, their radii should be as smooth as possible, avoiding sharp corners to eliminate flow interruption.

In an ideal duct, the gas flows in layers, a so-called laminar flow. Surface friction in the duct causes the velocity to decrease. The velocity increases from layer to layer, reaching its maximum in the centre of the duct. A consistent velocity profile is the result.

If the flow is perturbed, for example by obstructions, corners, irregular reductions or regular widening where the aperture angle is too large, flow interruptions and/or dead spots will occur, where turbulences form. This is called a turbulent flow. The velocity profile of a turbulent flow is very irregular. Turbulences formed by flow interruption cause pressure losses since they require energy, which is drawn from the flowing gas.

With the aid of computational fluid dynamics (CFD), the flow characteristics of the components involved in the process, such as fans, ducts and all other parts which come into contact with the media, can be simulated and optimised on the computer. Particular attention should be paid that the flow onto the impeller is the best possible as the effectivity of the fan depends significantly on this.

Figures 1 and 2 show the optimisation of the inlet duct on a double-inlet ID fan. Using plant sketches provided by the client, a 3D model was generated on which a CFD simulation was carried out.

Figure 1 shows the numerical flow simulation on the 3D model of the inlet duct in the original design.

Particularly noticeable are the acutely angled transitions and the dead spot at the end of the duct. This also shows up in the analysis of the simulation where flow separation of the flow lines can be seen at the above-mentioned points. The pressure losses are accordingly large. From the entry up to the end of the first branch, the pressure loss is approximately 260 Pa. From the entry up to the second branch, it is 430 Pa because of the turbulences seen on the right, caused by flow separation in the dead spot at the end of the duct.

Figure 2 shows the duct after optimisation. Here the critical points, such as the acute angles on the changes in section, have been shaped so that the changes in section are now smooth, thus allowing the flow to follow the contours without interruption. Furthermore, the dead spot at the end of the duct, where previously turbulences had formed resulting in losses in pressure and efficiency, has been removed.

Figure 3. Granulator scrubber exhaust fan in a urea granulation plant.

In the case of double inlet fans, particularly, it is important to have similar flow characteristics in both inlet ducts to keep the impeller in balance because axial thrusts cancel one another and, therefore, the bearings are under less stress.

By completely eliminating flow separation, it was also possible to reduce flow velocity, which has a positive effect on pressure loss.

In this case, the optimised geometry of the duct results in a pressure loss reduction of more than 75%. A smaller fan with a lower motor output can be used, thus resulting in a reduction in energy costs.

Variable speed control – precision energy saving

Process fans in fertilizer plants are usually designed for a maximum operating point 'rated', whereas the actual operating point 'normal' is achieved by reducing the air volume. This can be accomplished by variable speed control, control using regulating equipment, such as louver dampers, or a combination of both.

The 'rated' operating point defines the volume flow necessary for the process, plus hypothetical leakages, excess air and also a safety factor, defined by the API Standard or the project specifications. Usually, a margin of 10 – 15% is added to the volume flow at operating point 'normal' (15% if specified in accordance with API 560, see API 560 § E.3.1.2 b). The result is the 'rated' operating point. This is normal practice in order to have a capacity reserve to cope with any process fluctuations caused, for example, by climatic or process temperature fluctuations in the media handled, or to allow for a future increase in production capacity. Operation at maximum operating point 'normal' with control dampers fully open should be avoided, as an increase of the volume flow in such a way is not possible.

For economic reasons, variable speed control should be the preferred choice for regulating volume flow because the fan efficiency will then always be within its optimum range.

Because fans possess a quadratic load curve and the consumed power is cubically proportional to the speed, the power required can be reduced by approximately half if the speed is reduced by 20%.

However, fans are still commonly operated at a fixed speed, using control dampers for regulation.

The control damper is often only set one single time to reach the 'normal' operating point. It is then possible that the fan will run continuously for months or years in this state. This drastically reduces the fan efficiency.

When using variable speed control, almost any, even the smallest, operating point can be set. With damper regulation, severely throttled operation should be avoided, because when the set angle of the vanes is too steep (greater than approximately 60°), it can cause flow interruption or have other unwelcome effects. Vibrations, pulsations, increased noise emissions and, in the worst case, damage to the fan may be the result.

The investment costs are lower for a fan with a fixed speed motor and regulating dampers compared to a fan with a variable speed drive and frequency converter. The

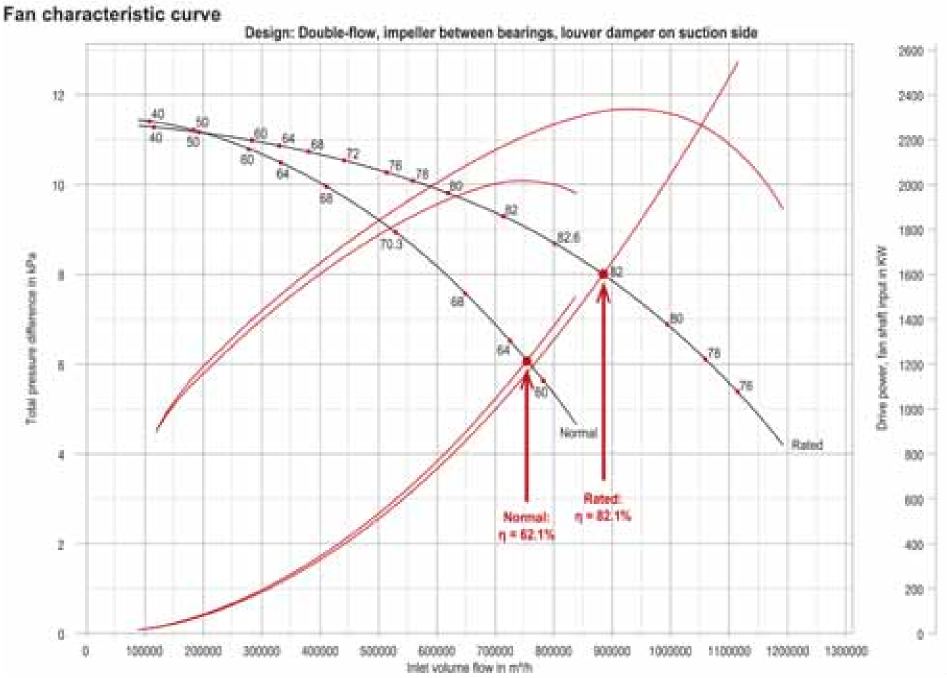


Figure 4. Characteristic curve fan with inlet damper control.

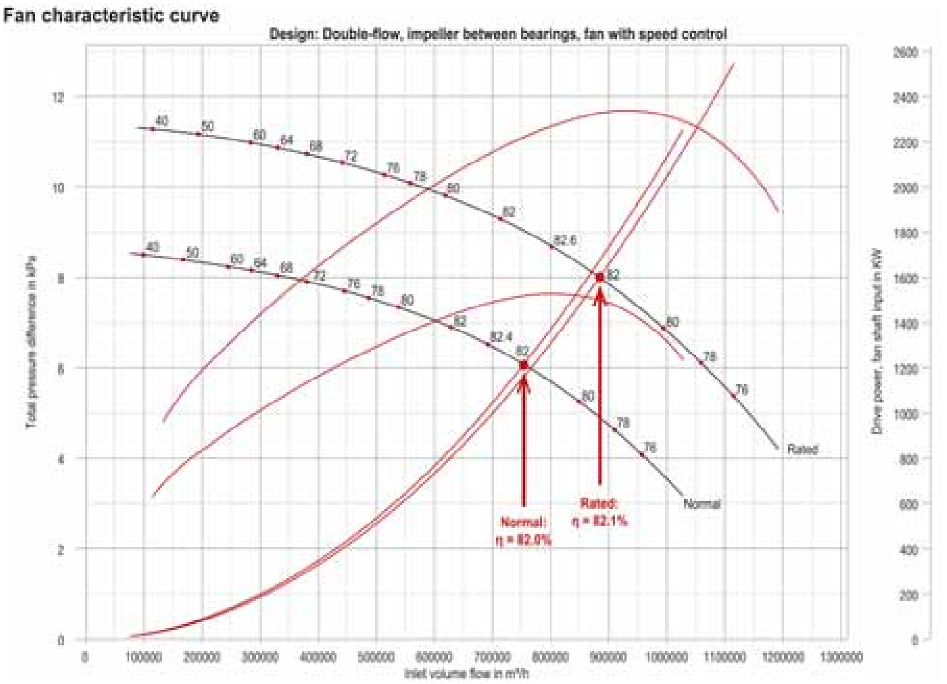


Figure 5. Characteristic curve fan with variable speed control.

Table 1. Comparison of the energy required and energy costs between speed and damper control

Type of control	-	Damper control	Variable speed control
Operating point	'Rated'	'Normal'	'Normal'
Shaft output (kW)	2326	2016	1519
Energy required per annum* (kWh)	20 375 760	17 660 160	13 306 440
Energy costs per annum** (euros)	2 424 715	2 101 559	1 583 466
*One year = 8760 hr			
**1 kWh = €0.119			

follow-up costs are, however, considerably higher because of the greater power demand. The higher initial outlay for a frequency converter is often recouped within a short time.

A variable speed control is not only of interest for new plants. When an upgrade is planned, a variable speed control can easily be fitted even to existing fans to help lower operating costs.

The following example (Figure 3) uses a fan downstream of a wet scrubber, operating as a 'granulator scrubber exhaust fan' in a urea granulation plant, to compare variable speed control and damper control. This example can, of course, be applied to any industry and application where more than a single operating point is needed. In practice, the fan takes exhaust air from the scrubber and conveys it to a stack.

The fan is intended to approach two operating points. Operating point 'normal' works with a mass flow of 756 300 kg/hr. The operating point 'rated' has a volume flow reserve of 15%. The mass flow is, therefore, at this point 869 745 kg/hr. The total pressure increase is 8000 Pa at operating point 'rated' and at operating point 'normal' 6080 Pa. The gas temperature at both operating points is 46°C.

The calculation is based on a double inlet, high efficiency centrifugal fan (arrangement according to AMCA 'Arrangement 3, DWDI'), with the following characteristics:

- Urea granulation plant.
- Granulator scrubber exhaust fan.
- Impeller diameter: 2735 mm.
- Rotating speed: 985 rpm.
- Motor output: 2550 kW.
- Constructional standard: API 673.

When observing the first case, the volume flow of this fan was equipped with two louver dampers, one mounted on each inlet box. The mass flow is changed by altering the damper vane angle (0° = damper fully open; 90° = damper fully closed).

The characteristic curve (Figure 4) shows regulation using louver dampers. The louver damper vanes are moved by 49.4° to approach operating point 'normal'. Because of the throttling effect, the lower characteristic curve 'normal' becomes 'steeper' in comparison with the characteristic curve 'rated'. It tips downwards to the right.

The pressure loss through the louver dampers reduces the efficiency, in this example, by 20% to 62.1% in comparison with the 'rated' operating point (82.1%).

The same fan with variable speed control shows at 'normal' operating point a completely different characteristic than with damper control (Figure 5). Here the efficiency of 82.0%, at a rotating speed of 849 rpm, is almost identical to the 'rated' operating point value of 82.1%. It is clear that with variable speed control, the fan characteristic curve is shifted in parallel. Since there are no pressure losses caused by throttling, the efficiency is at a similar level at both operating points with the variable speed control.

If one calculates the operating costs for one year based on actual electricity prices for the above comparison, the potential for savings becomes very clear. Presuming that the fan runs continuously for one year, then the actual operating time is 8760 hr/yr (365 days x 24 hr = 8760 hr).

The average electricity price for industrial customers in Europe (EU-28) during the last two quarters of 2015 was €0.119/kWh (source: European Commission/Eurostat). This gives the result shown in Table 1.

If the fan used in this comparison is operated with variable speed control instead of with damper regulation, then the annual savings are €518 093. The additional outlay for a frequency converter is recouped after a short time. The annual savings will have positive benefits for the company books.

If one considers that there is not only one fan installed in a plant but, for example, in the urea granulation plant there are, depending on the process, eight fans (of which six are large process fans), then one quickly reaches the conclusion that the annual savings potential would be much higher were speed regulation consistently used.

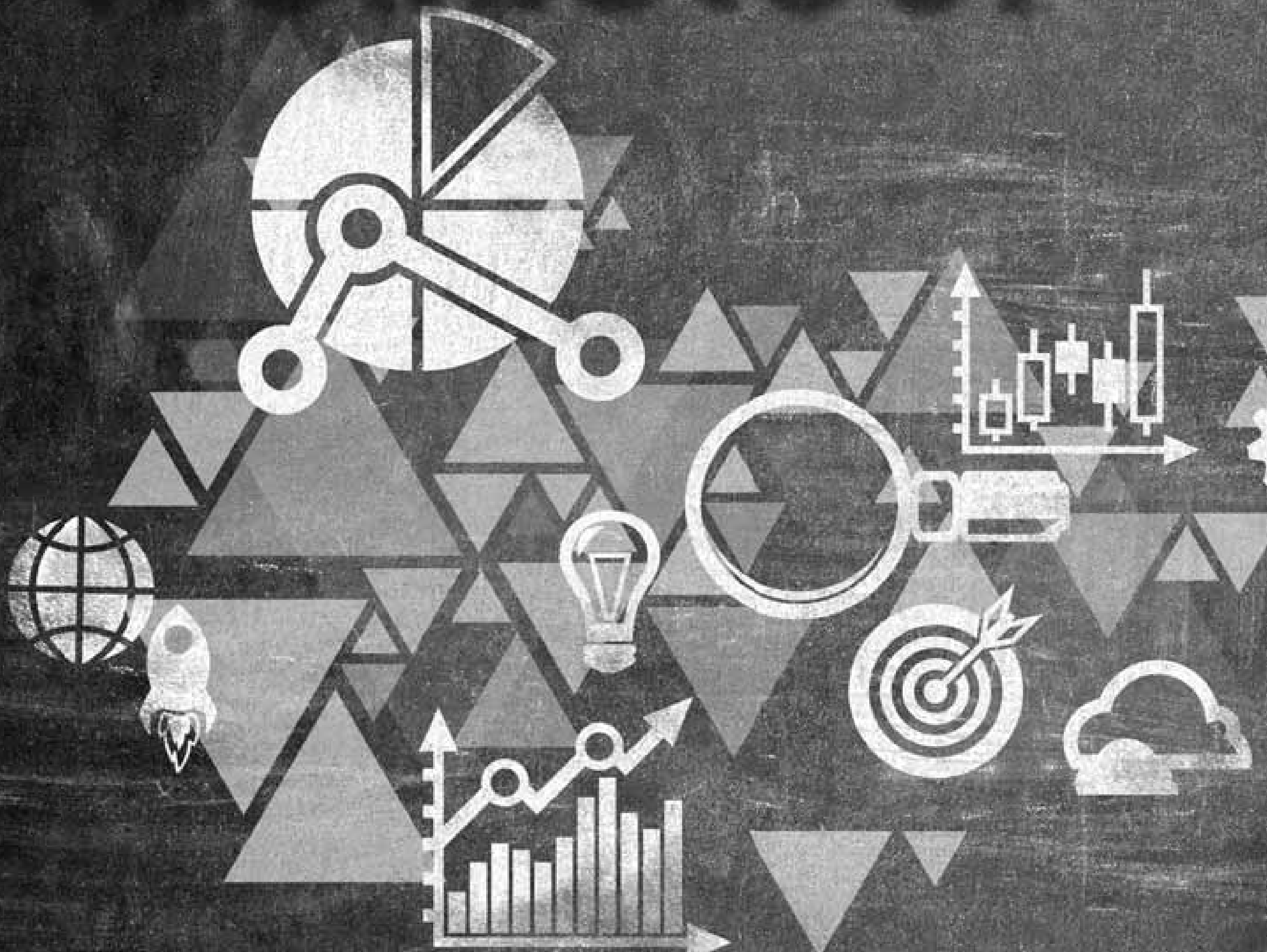
Using variable speed control proves to have many advantages:

- Energy optimisation.
- Precise and stable regulation.
- Startup at high torque with low starting current.
- Lower mechanical wear on fan and motor.
- Simple assembly as a result of dispensing with mechanical control equipment.
- Lower maintenance costs.
- Lower operating costs.
- Reduction of noise emissions at the partial load point of the fan.

Conclusion

A well-coordinated system consisting of an efficient fan, optimum intake and outlet ducting and highly accurate variable speed control increases the operating efficiency of every plant, reduces investment and maintenance costs and decreases any negative environmental impact. WF

OPTIMISING FLUIDISED BED TECHNOLOGY



Sergio Di Vincenzo, Boldrocchi, Italy, discusses how fan packages can help increase the performance of fluid bed technology.

Fans play critical roles in the fertilizer production process and the packages around them are equally complex. Without precisely engineered and manufactured fan packages, the process simply does not achieve objectives, and at times, the desired transformation process quite simply does not occur. Fans not only ensure the process functions, but well engineered and manufactured fan 'machinery trains' (all process equipment around fans) can help increase capacity and lower energy consumption – goals for all fertilizer plant owners and engineering, procurement and construction (EPC) contractors.

This article will highlight the importance of precise fan machinery train engineering and manufacturing to ensure performance objectives are met (or surpassed). It will also focus on the advantages of purchasing complete fan packages for urea granulation units, rather than buying the fan and the remainder of the systems piecemeal. These two points will be exemplified using a case study: an expansion project in North America that was commissioned a few months ago and that has been in operation since late 2017. The particular project involved fluid bed technology for a urea granulation unit.

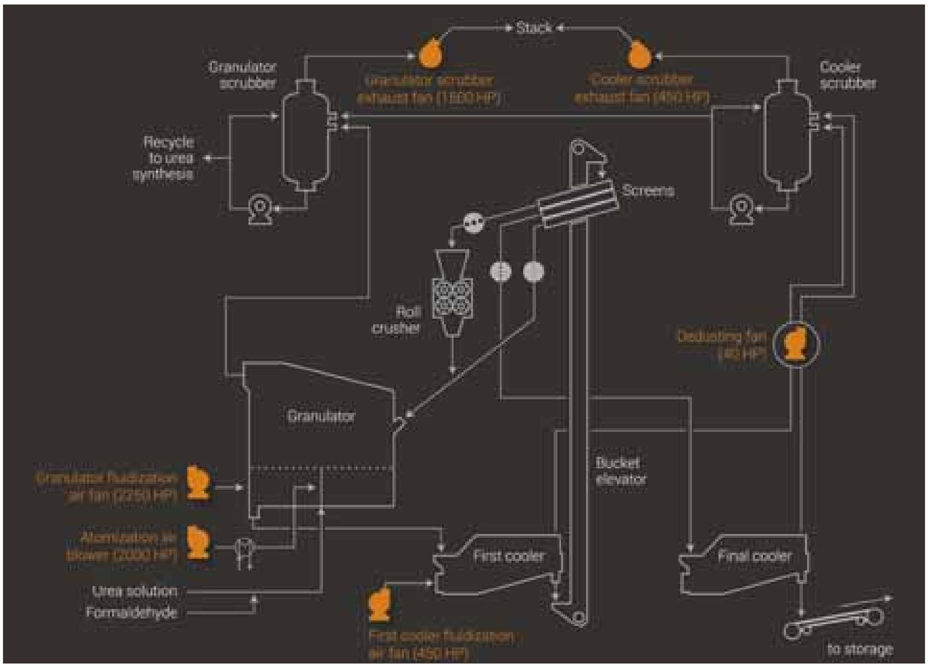


Figure 1. Boldrocchi supplies complete fan packages for multiple points in the urea granulation process.

Figure 2. Granulator scrubber exhaust fan being mounted at Boldrocchi's in-house manufacturing facilities in Italy.

New urea granulation unit

An existing nitrogen production plant was adding a new urea production unit, with the goal of increasing urea production capacity by 1800 tpd. Boldrocchi was hired in 2014 by KBR Houston to be the single point of responsibility for the complete fan machinery train of the fluid bed urea granulation unit, up to the main process interface. Therefore, Boldrocchi designed, manufactured, carried out the technical coordination and oversaw the installation of all main components, including the mechanical, instrumentation, acoustic, electrical and piping components.

Fan packages – a critical part of the urea granulation process

Process fan packages (fan machinery trains) are among the most crucial systems in the fertilizer process, and urea granulation units are no exception. Indeed, fan packages in urea granulation units are directly related to process – and therefore plant – reliability and performance.

Fan packages for this process are complex to design because their high ratings require careful mechanical design and their multiple components require the expertise of a number of different disciplines:

- Mechanical expertise for large rotating pieces of equipment.
- Acoustic expertise to achieve safe noise levels and reach noise reduction goals.
- Filtration expertise to ensure the final product is not contaminated.
- Thermal design expertise to ensure heated air is maintained at a targeted constant temperature to preserve the quality of final product.
- Expertise in the piping associated with the layout arrangement and lubrication system.
- Electrical and instrumentation expertise in order to define and program monitoring systems that protect the machinery. This includes anti-surge control systems for the atomisation air blower.

Another challenge is designing all these systems for a compact space, in order to minimise the impact on the overall layout of the urea granulation unit.

Fan scope of supply

For this project, Boldrocchi supplied complete packages around six fans and one blower, all designed according to demanding API 673 requirements for special purpose units to ensure maximum reliability and all designed to fit into the requested space requirements. Fan packages were engineered around the following:

- First cooler fluidisation air fan, rated 450 HP.
- Granulator fluidisation air fan, rated 2250 HP.
- Atomisation air blower, rated 2000 HP (main component of double-stage package).
- Granulator scrubber exhaust fan, rated 1500 HP.
- Cooler scrubber exhaust fan, rated 450 HP.
- Dedusting fan, rated 40 HP.

- Fumes extraction fan, rated 40 HP.

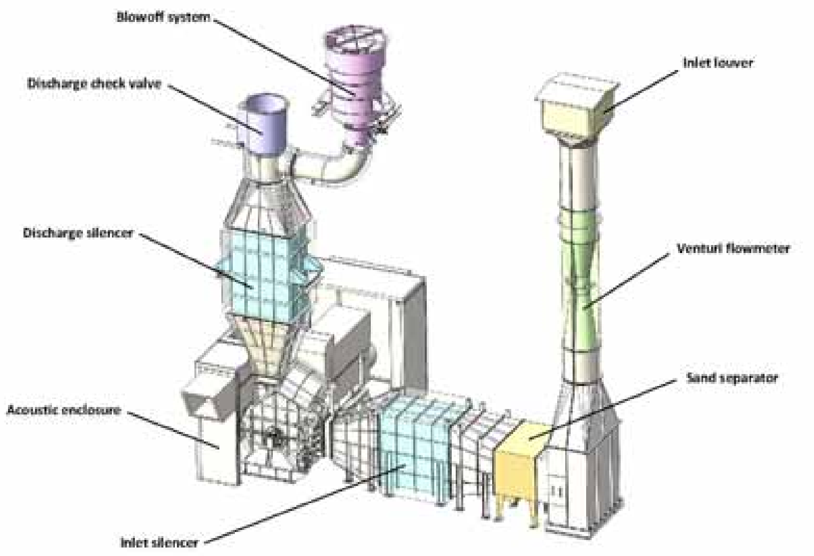


Figure 3. Rendering of Boldrocchi's atomisation air blower package.

Fluidising the bed: air fan packages

To fluidise the bed (where solid particles are subjected to a specified amount of pressure that forces the particles to mix and also behave like a fluid), air must be heated to a specific temperature, filtered, and sent to the bed.

Boldrocchi designed and manufactured two air fan packages (and one blower package, discussed below) that help fluidise the bed: a granulator fluidised air fan and a first cooler fluidised air fan. The team engineered each component properly to ensure that:

- Inlet filtration systems, consisting of high efficiency fibre filters, were removable, cleanable, and protected by rain protection louver dampers.
- Air preheaters, using steam, were designed to reach the requested thermal control over the process. These air preheaters have finned tubes, are heavy duty, ASME U stamped and were designed, fabricated and tested (with hydraulics tests) at Boldrocchi's in-house air cooled heat exchangers (ACHE) workshop. They were specifically designed with a reduced number of rows to minimise pressure loss and absorbed power, while reducing fouling, therefore reducing maintenance and making cleaning easier.
- Inlet silencers, absorption type, were placed directly at fan inlets to reduce noise emitted from both the ducts and the plant surroundings. Boldrocchi has a team that specialises in noise protection. They undertook noise studies of the air intake systems in order to design optimal silencers and duct insulation for these air fans. Noise reduction had to conform with strict noise regulations in the area.
- Inlet dampers, regulating the systems, were operated by pneumatic actuators to effectively save energy at different plant operating loads.
- Transition ducts, in flanged sections, were designed to optimise space requirements and reduce losses, hence improving the efficiency of the overall package.
- Electric medium voltage (MV) motors, the main drivers for all fans, were supplied and tested.
- All control logistics were programmed for normal operations, as well as for startup, shutdown and emergency situations.

Boldrocchi customised each of these air fan packages to the system's exact process parameters and was able to ensure such crucial elements as:

- The airflow rate caused the desired evaporation and attrition to allow for the targeted granule size.
- Clogging and impurities in the final product were avoided.
- The noise levels conformed to the area's strict regulations.
- The air preheaters minimised pressure loss and absorbed power, while reducing fouling, therefore making them easier to clean.
- The dampers helped save energy during partial load operation.
- Plant operators had easy control over the system.

Fluidising the bed: air blower packages

It is crucial to add an atomisation air fan or blower that is regulated very precisely and accurately because in a fluid bed unit, a pressure drop will affect the degree of material fluidisation significantly. Indeed, insufficient pressure translates to longer fluidisation time and may not create enough pressure for the exhaust damper to function.

Boldrocchi, therefore, engineered a double-stage atomisation air blower to achieve the high delivery pressure required. Designing this air blower required dedicated rotor analysis and the dimensioning of the complete lubrication system (by separate forced oil unit). The company included redundant accessories for long-term, reliable operation.

The team designed the atomisation air blower's package to include the following:

- An air intake system, complete with a silencer and a Venturi-type flowmeter, that ensured reliable flow measurement for blower control and anti-surge protection.
- A blow-off system, automatically controlled from the distributed control system (DCS), that works with the inlet flowmeter readings to prevent blower operation in surge areas where vibrations could lead to critical damages to the machines.
- An inlet filtration system, consisting of an inertial air filter for sand separation and an exhaust fan (scavenger fan), both of which ensure high efficiency and reliable airborne sand removal in any ambient conditions with a virtually maintenance free design.
- Discharge piping with a silencer and a check valve, to ensure blower isolation from the process during shutdown.

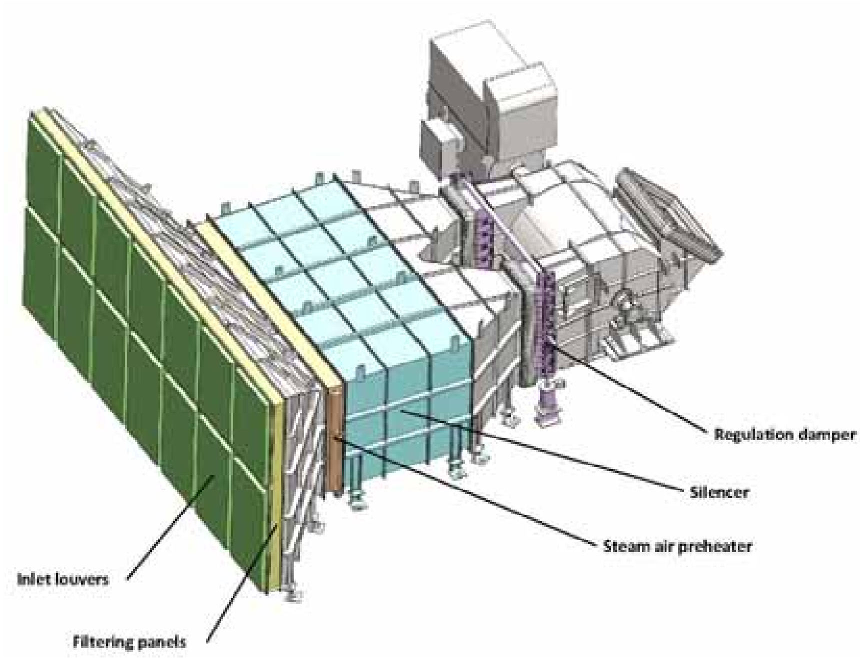


Figure 4. Rendering of an example of one of Boldrocchi's fluidisation air fan packages.

were also carefully engineered and built, as they are critical for reliable long-term operation. Both scrubber fans for this project were manufactured using SS316 casings and rotors in duplex stainless steel to avoid corrosion due to the high levels of acid condensation downstream of the granulator scrubber system. The parts of the fan shafts in contact with corrosive fluid were also jacketed in SS316. Finally, the seals at the shaft passages, both labyrinth-type, were built in polytetrafluoroethylene (PTFE), and were designed to eliminate corrosion related problems in critical areas of condensation where the shafts met ambient air.

- An acoustic enclosure that reduces noise to 85 dBA (this level includes the noise from the ventilation fans and internal lighting). Boldrocchi's noise protection experts did a noise study of both the acoustic enclosure and the blow-off silencer and engineered an acoustic enclosure that would ensure such high noise reduction targets.
- An inlet damper, operated by a pneumatic actuator, that regulates the system and is designed to save energy at different plant operating loads.
- An electric MV motor as the main driver for the unit.

The atomisation air blower package was designed as a walk-in with inspection doors for operator maintenance, an internal lighting system, heat extraction fans with switch panels that can select local operation, profiled columns and a base with removable sandwich panel walls, which are fire resistant and weatherproof for easy assembly/disassembly in case of rotor or motor removal.

The lube oil system is designed according to API 614 and feeds the fan and turbine bearings with fresh oil cooled by a TEMA C water-cooled heat exchanger. The bearings on the system are sleeve type with common forced oil lubrication for the complete machinery train. The oil is pressurised by a shaft-driven main oil pump. An auxiliary motor-driven standby pump is to be used as both a backup and a startup pump to ensure reliable backup.

Scrubber fans

A fluid bed granulation unit has two scrubber fans: a granulator scrubber and a cooler scrubber. The challenge with these fans is that there is high potential for corrosion and they undergo significant stress. There is also a high risk of vibration and imbalance as urea dust can easily accumulate on scrubber fans and this urea dust can unbalance the rotating parts and create high vibration levels.

The scrubber fans had to combine corrosion protection with high stress capabilities. Their construction and controls

Monitoring the system

High quality urea granules depend on the plant operator's ability to monitor various process parameters. Boldrocchi, therefore, supplied a fully packaged unit with 100% redundancy on all auxiliary components (filters, coolers and oil pumps) and continuous monitoring of the main parameters. The monitoring system was designed to be intelligent and monitor all variables to ensure long-term reliable operation and offer plant operators control in case of faults.

The customised local instrumentation module sends alarm and trip signals in case of oil pressure loss, temperature hikes or low levels. Boldrocchi also supplied all field instrumentation for machine monitoring connected to plant's main DCS/ESD system.

Testing

A large space is required to test these systems, and Boldrocchi's Italian workshops provide the space, a large test stand and the high power requirements necessary. Technicians were therefore able to perform successful functional tests of all the equipment in-house before shipping the solutions, careful to ensure proper settings and reliable operation. This testing is a crucial step on such highly engineered applications.

Erection and commissioning

Boldrocchi fast-tracked this project and was able to deliver all packages within a short nine months, whereas a typical delivery would take 11 months to a year. Delivery was on time. Erection and commissioning were overseen by a Boldrocchi site expert, who was on-site for two weeks to ensure the proper installation and smooth operation of all fan packages.

Conclusion

Fan packages for fertilizer plants, including processes such as urea granulation, are highly complex and can sometimes be considered mini-plants onto themselves. Engineering on the fans and on the package components must be precise in order to achieve the targeted production/process goal. So much in these processes depends on fan package performance. WF

MOVING AIR, MOVING FORWARD

Margaret Wood, New York Blower Co., USA, looks at the importance of industrial blowers and fans in the fertilizer industry.

Worldwide growth in fertilizer demand continues to drive innovation in literally every facet of production, from the most fundamental new process technologies to the construction of new plants that will employ them. Multiple design engineering challenges include energy efficiency, regulatory pressure and safety in tension with quality, efficient throughput and, ultimately, profitability. An ever growing, constantly evolving choice of air movement solutions is essential in order to meet those challenges and enable the innovation from which they spring.

Figure 1. Surge limiting pressure blowers can be used for fertilizer applications involving high pressure and low flow.

Figure 2. Vaneaxial fans are most typically used in fertilizer applications where space is at a premium.

In fertilizer production, air movers – industrial blowers and fans – are in many ways the power behind air handling, fine particulate control and pneumatic conveyance. Requirements include the ability to generate controlled high pressures and flowrates, operate reliably in highly corrosive, abrasive and high temperature environments, simplify maintenance and, most importantly, offer facility and system designers the ability to move, contain, redirect and control airflows in even the most highly specified applications. These may include dust control, pollution control, process heating, pneumatic conveying, material conveying, scrubbers, oxidisers and dryers.

Given that nitrate fertilizer dust is based on a volatile substrate that poses a particular ignition risk, while other types may include caustics and heavy metals, dust control is of critical importance throughout the manufacturing process as well as in handling. Capture and control of such emissions are accomplished by creating air movement. A wide range of fan designs may be used to move air through a filter or process scrubber. Fans may be installed on the clean side of a given capture device or the dirty air side depending on system requirements.

New York Blower Co. offers a complete array of centrifugal and axial products appropriate for fertilizer industry applications. Both centrifugal and axial fan designs may be appropriate for a given application. In general, axial fan designs are preferable where space is at a premium.

Fans can range from standard, predesigned fans to highly customised or entirely custom-designed products. Off-the-shelf designs can be modified to meet specific application needs, such as zero leakage construction, abrupt temperature change, cyclical speed changes, etc.

Fans are designed to offer the highest aerodynamic efficiencies compatible with specific systems and gas-stream requirements. Fan construction includes mild steel, high strength alloy steels, aluminium, 300 series stainless steels, Inconel, incoloy, hastalloy, titanium and other exotic alloys. Special coatings can be applied based on the application, and consist of baked phenolics, epoxies and rubber linings.

Custom designs can be provided for the following:

- Flows over 1 million ft^3/min. / 472 m^3/sec.
- Static pressures beyond 150 in. wg / 37.4 kPa.
- Centrifugal wheels beyond 150 in. / 3810 mm dia.

Each application is analysed on its own performance and unique design requirements. Designs are based on computer analysis of wheel metallurgical stresses, shaft critical speed and bearing limitations. Predesigned fans can be modified or custom fans are designed in accordance with customers' specifications. They are available in arrangements 1, 2, 3, 4, 7, 8, 9 and 10 – all the standard design features of the industry plus custom sizes, DWDI, inlet boxes, double-width construction, split housings, independent pedestals, liners, elevated temperatures, alloy construction, gas tight construction, etc.

Two fan lines that would be suited for fertilizer applications are vaneaxials and pressure blowers. Vaneaxial fans are best suited for high pressure ventilating and industrial process applications requiring air flow through compact space. They are available in both fixed pitch and adjustable pitch units. Fixed pitch vaneaxial fans are belt-driven with flows to 100 000 ft^3/min., pressures to 8 in. wg, multiple choices of hub ratios and fan mounting positions, and 15 belt-drive sizes from 12 in. through 60 in.

Adjustable pitch vaneaxial fans are direct-drive units, which permit performance adjustments via blade adjustments (without special tools) in the field without V-belt drives or adjustable speed controllers. As such, they offer very attractive energy efficiency. Available in 11 sizes from 21 in. to 60 in., they offer flows up to 120 000 ft^3/min., pressures to 20 in. wg, and two mounting configurations.

Surge limiting pressure blowers are designed for high pressure, low flow applications, which include elevated temperatures, corrosive gas streams and stringent leakage requirements. They are designed to reduce surge and continue normal operation as process conditions approach shutoff without the need for auxiliary equipment/accessories. They are available in wheel sizes from 22 in. dia. to 98 in. dia., with flows to 30 000 ft^3/min., pressures to 180 in. wg, temperatures to 1200°F, and a choice of belt or direct drive. A full range of customisation options includes protective coatings and insulation, heat fan construction, special diameter construction, spark resistant construction, special alloy construction, etc.

The company follows a custom in-house quality control programme proven efficient through years of experience. AWS D14.6 certified welders and documented weld procedures are used on all fans, not just when specified by customers. NDT checks, such as dye penetrant, mag particle, X-ray, ultrasonic and helium spectrometer leak tests, are performed by both in-house personnel and independent testing services.

In addition, the company dynamically balances every fan shipped, up to 150 in. dia. and 25 000 lb and offers field service for in-field alignment, balancing and analysis.

Conclusion

When choosing fertilizer equipment, it is best to consider all of the application requirements and design features. Selection criteria, such as the amount of particulate and the volume of flow needed, are two important pieces that dictate which piece of equipment will work best for the job. The use of selection software or a design engineer familiar with the applications can help to select the right equipment, and make sure efficiency is factored into the decision. WF

DOME SWEET DOME

Stewart Ulrich, Monolithic Domes, USA, outlines the benefits that dome-shaped storage facilities can bring to the fertilizer industry.

The dry bulk storage industry is a sprawling one, taking commodities from shipping containers to storage facilities all over the world. A major aspect of this industry are the structures that hold these commodities. As a home protects its residents, the job of these structures is simple: protect the commodities that are stored inside. Whether it is grain, coal, fertilizer, ammonium nitrate, cement, coal, fruits, vegetables, pesticides, or any number of other commodities, they need to be protected from the elements.

One structure out there is creating a safe and secure storage environment: the Monolithic Dome. By having a round structure, there are no corners and thus the space inside the dome is maximised for optimal storage capacity.

These unique structures use a specified construction method, which sets them apart from other structures. A Monolithic Dome is constructed by starting with a concrete ring foundation, reinforced with steel rebar. Then, a large membrane known as the Airform is placed over the foundation and inflated using blower fans. Once the membrane is properly inflated, 3 in. of polyurethane foam is sprayed to the interior surface of the Airform. Steel reinforcing rebar is attached to the foam using a specifically engineered

Figure 1. The exterior of a Monolithic Dome blend plant in Bryan, Texas, US. By Monolithic Dome Institute.

Figure 2. Interior of the blend plant during construction. The steel rebar can be seen. By Monolithic Dome Institute.

layout of horizontal and vertical rebar. Finally, shotcrete, a special spray mixture of concrete, is applied to the interior surface of the dome.

These components ensure the strength to withstand natural disasters. Monolithic Domes have been proven to survive fires, earthquakes, tornadoes, and hurricanes. Several domes have been built in recent years in the US Midwest, where tornadoes are prevalent. Another dome went right through the eye of a hurricane in the Florida Keys in last year's hurricanes. The Category 4 storm damaged surrounding structures, but the dome came out unscathed.

Another benefit to a dome is energy efficiency. Due to the foam insulation that makes up the dome's walls, the structure moderates the temperature inside of the dome. It takes less energy to heat or cool a Monolithic Dome than it does to heat or cool a super-insulated metal building or a conventional house blanketed in an airtight wrap. This temperature regulating quality of these structures makes them particularly attractive to the storage industry, and to fertilizer storage in particular.

Fertilizer has always been a sector of the dry bulk storage industry that has proved difficult to keep. One of the largest issues with storing this commodity is its corrosive properties, often ruining handling and other equipment at the storing site. Moisture is the culprit; if water enters or condensation forms inside the storing site, it quickly begins to degrade the fertilizer and rust forms. This has long created headaches and added expenses for companies to replace such equipment.

Monolithic Domes use technology that safely maintains the quality of the product stored inside. These structures provide a safe and maintainable space for these commodities to be stored. By creating a concrete space around the commodity, they are protected from the outside world.

One example of the effectiveness of this storage method is with ammonium nitrate – a colourless, crystalline substance that is often used in fertilizers and explosives. This commodity can be highly explosive if it comes in contact with an open flame. This aspect of ammonium nitrate creates a tricky circumstance for those charged with storing it.

One incident in recent years really emphasised the importance of safely storing ammonium nitrate. In April 2013, a fertilizer plant in West, Texas, US, containing 30 t of ammonium nitrate exploded, killing 15 people and damaging 150 buildings. Since then, companies have turned to domes to safely store commodities such as ammonium nitrate. A 52 ft dia. dome was built in Whitewright, Texas, US, to safely house 1000 t of ammonium nitrate. Another facility in Bryan, Texas, has built two Monolithic Domes – a large blending plant and a smaller dome for use as a warehouse for various bulk chemicals.

One aspect of a Monolithic Dome that makes it an effective storage structure for fertilizer is its insulation. As temperature changes, fertilizer changes properties. It can harden up and require time to break it up. Another possibility is for the fertilizer to liquefy, which can eat away concrete. By keeping fertilizer in an insulated dome, the product stays in a pure state.

On the issue of the corrosive nature of fertilizer, which can ruin the handling equipment, Monolithic Domes use air conditioning to combat the corrosiveness. Under this system, the aim is to moderate the temperature and keep it at a moderate rate. An air-conditioned building means the humidity inside can be lowered and moisture can be removed. This removes the corrosiveness of the fertilizer, which means the equipment will last longer.

A Monolithic Dome blend plant helps to safely store and manage commodities. Instead of a dome that is completely open for storage, these buildings are modified to better suit storage requirements. There is an open central area of the dome, but these structures have different sectioned-off areas around the edge of the dome. The purpose of these separate areas is to be able to store different types of fertilizer without mixing and cross-contaminating. A small front-end loader is used to retrieve different types of fertilizer from the compartments needed to blend fertilizer for a specific need.

This type of setup for a company is valuable and can save money on replacing equipment. The fertilizer product is held well and is less corrosive when stored in this manner.

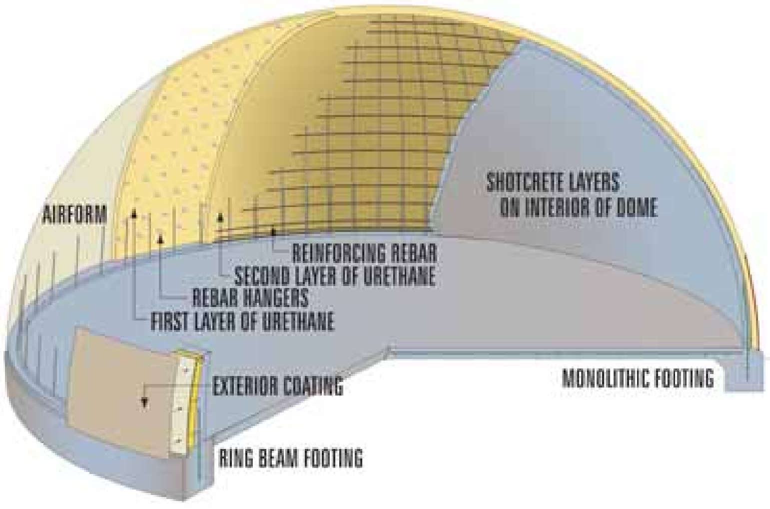


Figure 3. A cutaway graphic of the makeup of a Monolithic Dome. By David Collins.

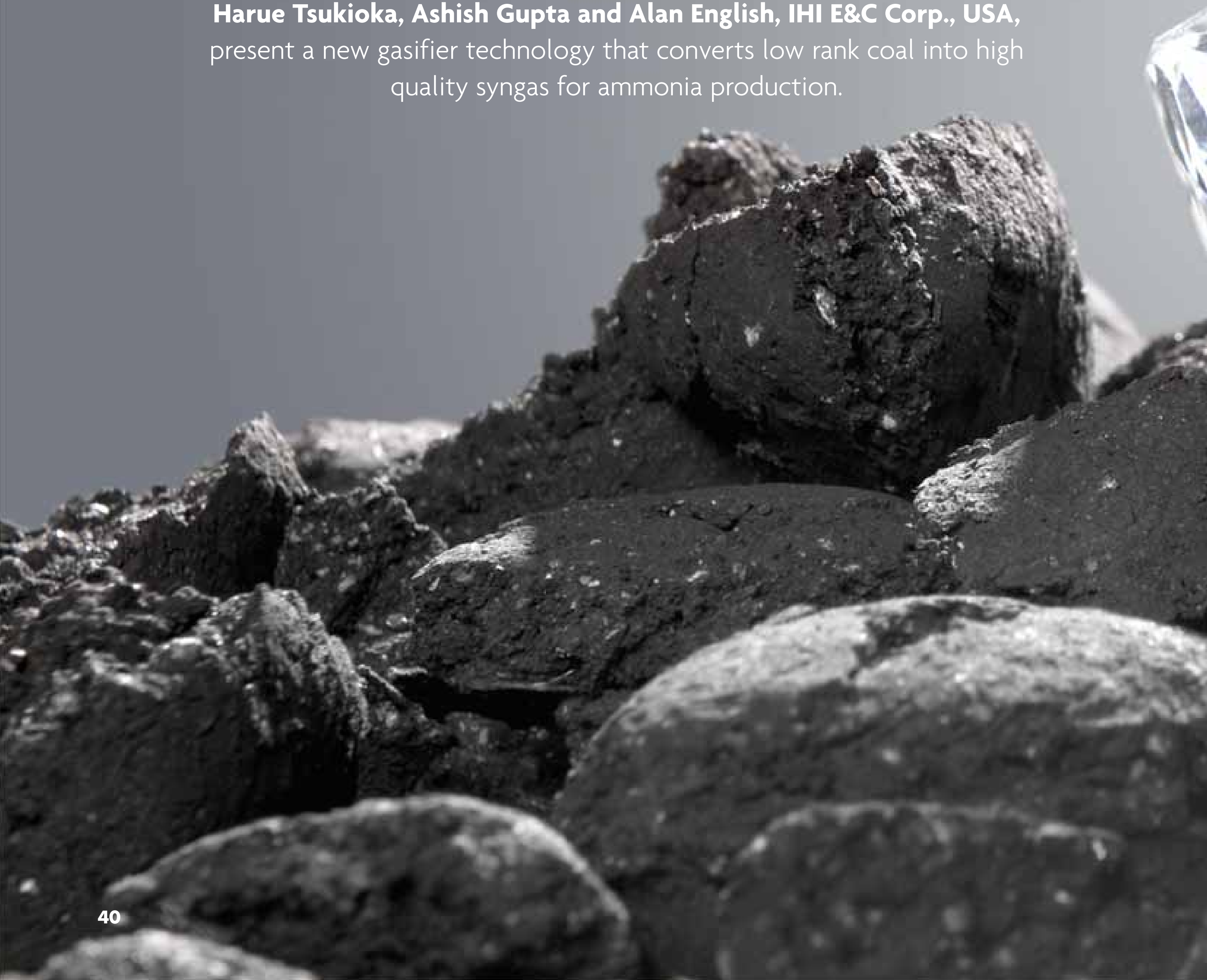
Another reason Monolithic Domes are valuable for storage purposes is because they are fire resistant. If a fire is burning on the outside, the product will remain safely inside the concrete dome. Due to their concrete makeup, there is no wood inside the structure to burn. Domes are blast resistant, making them an ideal storage facility for potentially dangerous materials. In addition to fire protection, the climate of these structures can be easily controlled. Due to their energy efficiency, the temperature inside of the domes is easily maintained. Less energy is required to cool the air in fertilizer domes, for example, and decreasing the humidity. This can be cost-saving for companies and their operations.

Conclusion

Monolithic Domes provide safe and secure storage for any commodity they store. These structures have many advantages, including energy efficiency and disaster protection, that make them attractive for the bulk storage industry. WF

A DIAMOND IN THE ROUGH

Anchan P. Kayamori and Shuzo Watanabe, IHI Corp., Japan, and Harue Tsukioka, Ashish Gupta and Alan English, IHI E&C Corp., USA, present a new gasifier technology that converts low rank coal into high quality syngas for ammonia production.



The pace of development of gasification technology has varied over the years per the prevailing market forces, regulations and environmental concerns. Although the pace has varied and multiple gasification technologies have matured, most of them use coal as feedstock, though some of them can utilise biomass, waste or other carbonaceous materials.

Gasification of coal/biomass offers an effective solution to the world's energy/chemical needs.[1] The product of gasification is synthesis gas, which is versatile and can be utilised in a number of ways. The synthesis gas can be used as fuel to power boilers, or can be used to produce hydrogen, ammonia, methanol or other chemicals. Given the current unprecedented growth in natural gas production in the US, most new plants are slated to use natural gas as their feedstock to produce synthesis gas via reforming. Though gasification has become less attractive in recent times in North America, it is still an attractive option in other parts of the world.

Given the environmental concerns for greenhouse gas (GHG) emissions, gasification offers a potential solution. Gasification of coal together with carbon capture and storage/usage can provide an environmentally benign source of energy from the abundant coal reserves in the world. Gasification of biomass can provide a renewable source of energy from non-fossil feedstock. Gasification of organic waste, such as municipal solid waste, has the potential to not only provide

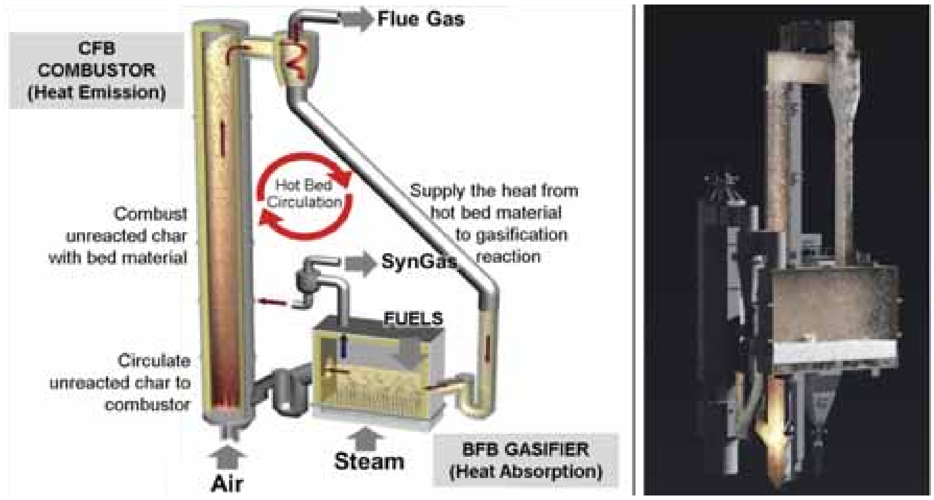


Figure 1. Scheme and 3D model of Twin IHI Gasifier (TIGAR®).

energy source, but also to provide a solution for waste disposal.

Over the years, multiple corporations have developed gasification technologies. Some gasification technologies have already seen commercial deployment while others are at demonstration or pilot stage. Several gasification technologies are now being licensed by major corporations. The Great Plains Synfuels plant in North Dakota is a commercial scale coal gasification plant in the US for converting lignite coal into synthetic natural gas (SNG). The plant employs Lurgi gasifiers and first started producing SNG in 1984. KBR TRIG® gasifiers are being used for the construction of a major integrated gasification combined cycle (IGCC) plant in Kemper County, Mississippi. There are also several smaller gasification plants operating in North America. Saudi Aramco is using Shell gasifiers for its commercial scale Jazan IGCC project in Saudi Arabia currently under construction. Reliance India Ltd is using CB&I E-gas gasifiers at the Jamnagar refinery in India, which is currently under the process of startup. In addition, there are several different gasifiers operating in China.

Most of the operating gasifiers are fixed/moving bed gasifiers involving entrained flow. This article describes a fluidised bed gasifier, the Twin IHI Gasifier (TIGAR®) developed by IHI Corp., Japan, and its proposed use in the construction of a 2500 metric tpd ammonia plant using lignite coal as the feedstock. The proposed location for the coal-to-ammonia plant presented in the current case study is the new industrial complex in East Kalimantan, Indonesia.

Technology

TIGAR is one of the clean coal technology (CCT) efforts of IHI Corp. to develop effective technologies for turning lignite, which is a low rank coal with high moisture and biomass, into high quality syngas. As shown in Figure 1, it is a dual fluidised bed steam gasifier, consisting of a bubbling fluidised bed gasifier and a circulating fluidised bed combustor, and operates efficiently under atmospheric pressure and low temperature. In the gasifier, steam is utilised as a gasifying agent, coal(biomass)-steam reactions occur and are endothermic reactions.

The main reactions involved in these processes are as follows:

- Cracking: $pC_nH_x \rightarrow qC_mH_y + rH_2$
- Steam reforming: $C_nH_x + mH_2O \rightarrow (m+(x/2))\ H_2 + nCO$
- Methane formation: $CO + 3H_2 \leftrightarrow CH_4 + H_2O$
- Carbon formation: $C_nH_x \rightarrow nC + (x/2)\ H_2$
- Water gas shift: $CO + H_2O \leftrightarrow CO_2 + H_2$
- Carbon/soot-steam reaction: $C + H_2O \leftrightarrow CO + H_2$

The target product of TIGAR is synthesis gas (syngas) from the devolatilised volatile matters and gasified chars, while the remaining char will be transported to the combustor and air combusted with the bed material, then circulated into the gasifier as the heat carrier and heat source for the endothermic coal(biomass)-steam reactions.

Current developments

Indonesia's natural gas reserve faces limitation in capacity, leading to concerns in meeting domestic and export demand.[2] The government has launched an aggressive policy to promote alternative choices to cover this critical demand in natural gas, especially for domestic consumption. The ammonia fertilizer industry is the largest consumer of domestic natural gas and is trying to use alternative feedstocks to replace the natural gas. Lignite is the most abundant coal resource in Indonesia. Due to its low energy value and high moisture content compared to other coals, the utilisation of lignite for any application is challenging. The technology to turn abundant lignite into an energy source that can replace natural gas is highly anticipated.

The TIGAR prototype plant project for ammonia production using 50 tpd of Indonesian lignite commenced construction in 2012. The plant started operation in 2015 and has been operating for over 4000 hr in total up to now, with a successful 1015 hr of continuous operation in a long-term endurance test. The purpose of this prototype plant is to evaluate the maintenance durability in long-term operation using Indonesian lignite to confirm the TIGAR performance and reliability, which will be reflected in commercial plant design and engineering. Moreover, it will operate with various kinds of coal and biomass before demolishing the plant in 2018, making way for the next stage of commercialisation.

Features of the technology

TIGAR technology has a uniform, moderately low temperature throughout the gasifier (800°C), offering the following advantages:

- Lower heat removal required in downstream units leading to better efficiency.
- Increased life of system components, including the vessel refractory.
- Moderate temperatures in the gasifier are sufficient to provide high carbon conversions, while ensuring that excess tar formation does not occur.
- Moderate temperatures ensure that slag formation does not occur in the gasifiers. This makes the technology well suited

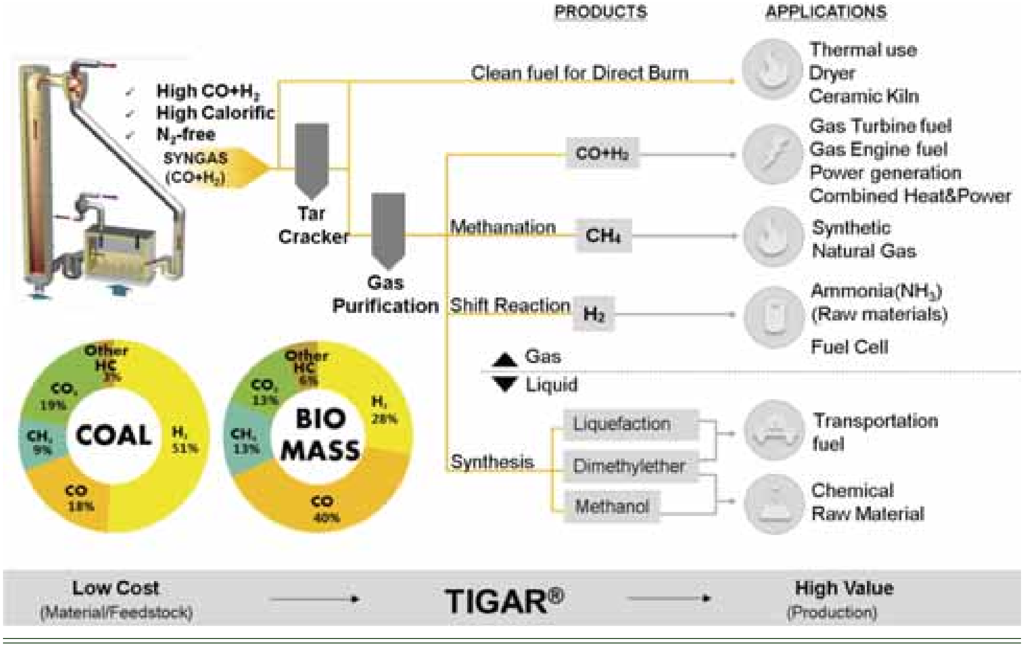


Figure 2. Application of TIGAR technology.

to low rank coals, i.e. coals with high ash and moisture contents.

Another feature of TIGAR gasifiers is their moderate oxidant requirement as the main gasification agent is steam. TIGAR gasifiers use steam as the primary oxidant, while a smaller amount of oxygen is used in the tar crackers.

A distinguishing feature of the gasifiers is that they operate at almost atmospheric pressures, hence the feed system is relatively simple and less capital intensive.

TIGAR gasifiers can take high moisture content coal, which, once vaporised, becomes feed for the gasification reaction. Coal dust is acceptable to the system as the feed is crushed coal.

In summary, the gasification technology has the following advantages:

- Lower CAPEX and simple operating and maintenance (O&M).
- High reliability and availability because of lower pressure and temperature in operation and the use of proven technologies (IHI circulating fluidised bed (CFB) technology).
- Multi-fuel application for coal, biomass, plastic wastes, organic sludge, heavy oils and their co-utilisation.

Process overview for ammonia production

As shown in Figure 2, the syngas produced from gasification can be used in multiple ways. The current case study describes the production of ammonia from syngas.

The major process and utility blocks encompassed by the project are as follows:

- Coal receipt, storage and feeding.
- Coal gasification.
- Tar cracking.
- Syngas scrubbing and cooling.
- Syngas compression.
- Sour shift.
- Syngas cooling and steam generation.
- Acid gas recovery.
- Nitrogen wash.
- Ammonia synthesis.
- Air separation.
- Sulfur recovery.
- Utility systems.
- Ammonia storage and offloading.

The major building blocks required for ammonia production from syngas are shown in Figure 3.

Coal receipt, storage and feeding

Coal (lignite), at under 50 mm in size, is transported from the coal mine to the jetty port of the plant by ship and then to the coal yard by coal unloader facilities and conveyors. The coal impurities are separated by the magnetic separator. Coal is crushed and sieved to under 10 mm before being taken to the bunker by conveyors for feeding the gasifiers.

Coal gasification

1000 tpd of lignite coal raw material is fed to the gasifiers to the fluidised bed. The gases generated in the gasifiers are discharged from the top of the gasifiers to the cyclones and then to the tar cracker unit for the tar elimination.

Combustor

The sand and char, as the residue from the gasification reaction exits the bottom of the gasifier, is transported past the outlet loop seal to the combustor. The combustor combusts the char by the pre-heated air supplied from the bottom to give the heat to the circulating bed material, which will circulate past the inlet loop seal and back to the gasifier. The combustion flue gas goes to the outlet duct that connects to the combustor cyclone, where flue gas and bed material are separated. After the cyclone, the bed material is passed back to the gasifier while flue gas will pass through the heat recovery area to generate steam. An opacity meter and gas analyser (SO_x, NO_x, O_2, CO and CO_2) have been established to confirm the environmental regulatory levels of the combustion gas.

Tar cracker

Tar in the syngas is cracked at a high temperature by releasing oxygen into the furnace. The syngas exits the bottom of the tar cracker and passes to the gasifier heat recovery area to generate steam. The syngas after tar treatment will pass to syngas scrubbing and cooling units to reduce the temperature.

Scrubbing and cooling

The syngas scrubbing and cooling system consists of several scrubbers, which aim to completely remove dust, tar and heat in the syngas supplied from the outlet of the tar cracker. The syngas is cooled down from 400°C to 45°C at the outlet of the scrubber system. The effluent and water discharged from the scrubbers are supplied to sludge decanter units to remove sludge from the water. One part of the water is recycled back to

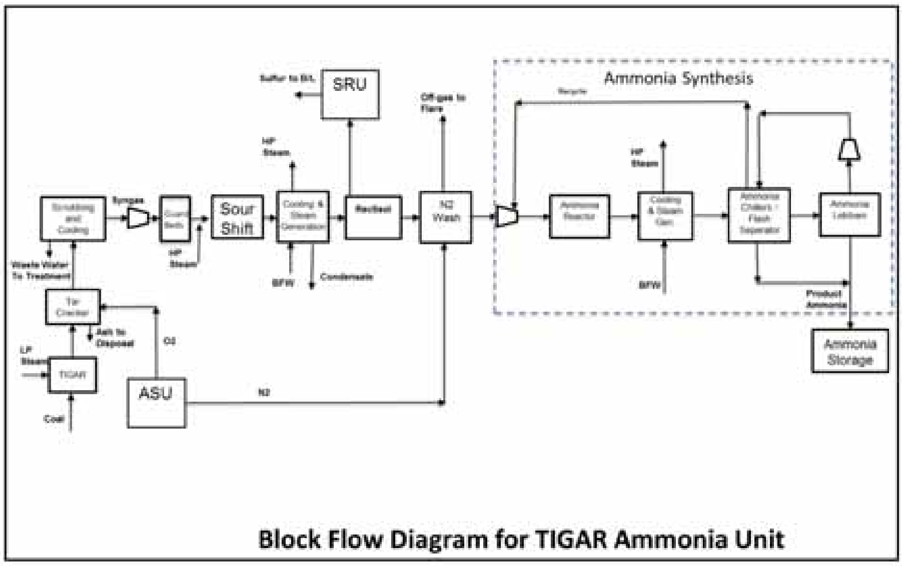


Figure 3. Major building blocks for ammonia production.

be utilised at the scrubber systems and another part is transferred to waste water treatment system.

Syngas compression

Upon exiting the the syngas scrubbing and cooling system, the syngas is compressed from ambient pressure to approximately 3800 kPag by a five-stage centrifugal compressor driven by a steam turbine.

Sour shift

The synthesis gas is a mixture of gases of which only hydrogen is used in the production of ammonia. In order to increase the hydrogen content of the syngas, the compressed syngas is sent to a two-stage sour shift reaction system. Prior to entering the first stage shift reactor, the syngas is cleaned of any residual impurities (such as particulates and mercury) in a guard bed and mixed with superheated high pressure steam. The water gas shift reaction is an equilibrium reaction that converts CO to CO_2, producing additional H_2 from water: $CO + H_2O \leftrightarrow CO_2 + H_2$

Acid gas recovery

The Rectisol® system[3] is used for acid gas (CO_2) recovery as it offers significant advantages compared to other systems (e.g. amines, aMDEA). Although the initial capital cost for a Rectisol system is generally higher, the operating costs are lower. Methanol as a solvent is also capable of removing most undesirable trace components in the feed gas and is relatively inexpensive to replace once degraded.

Nitrogen wash

The nitrogen wash is mainly used to purify the synthesis gas to a condition suitable for ammonia synthesis. The nitrogen wash serves to further remove residual impurities, such as CO, Ar and CH_4, from the synthesis gas and to establish a stoichiometric ratio of H_2/N_2 of 3:1 as required for ammonia synthesis.[4]

Ammonia synthesis

Ammonia synthesis from an H_2/N_2 mixture is usually carried out in the temperature range of 390 – 510°C over an iron catalyst promoted with oxides of alkaline and alkaline earth metals.[5] The formation of NH_3 from H_2 and N_2 is an exothermic reaction: $3\,H_2 + N_2 \rightarrow 2\,NH_3$

Ammonia storage and offloading

The liquid ammonia is pumped by the ammonia product rundown pumps to the ammonia storage tank for storage. The ammonia storage tank is equipped with a refrigeration package to condense any boil-off ammonia gas from the tank. The tank holds approximately 50 000 t of liquid ammonia. The tank is double walled and operates at atmospheric pressure. The liquid ammonia is loaded onto ships by the use of the ammonia load-out pumps and the loading arms.

Sulfur recovery unit

The sulfur recovery unit (SRU) will remove hydrogen sulfide (H_2S) from the acid gas generated in the acid gas recovery (Rectisol) unit. The H_2S is converted to elemental sulfur, which is recovered as a solid cake. The purge gas from the SRU is sent to the flare. Several options were considered and in the current case the Merichem Lo-Cat® unit was determined to be most appropriate for the system.[6]

Air separation

The air separation unit (ASU) will supply gaseous oxygen, gaseous and liquid nitrogen, instrument air and service air per requirements. The TIGAR coal-to-ammonia process uses oxygen as the oxidant in the tar cracker unit. Liquid nitrogen is used in the nitrogen wash unit. Oxygen is provided by a cryogenic ASU supplied by a suitable process licensor. To maintain a reasonable size and energy consumption of the ASU, oxygen purity of approximately 99 mol% has been selected for the process.

Summary

TIGAR gasifiers and the proposed building blocks leading to ammonia production have been described. The gasifiers have been developed based on several decades of experience in building similar circulating fluidising bed reactors. The demonstration plant has shown encouraging results as the technology advances to next stage. Ammonia production using lignite coal in Indonesia can lead to the utilisation of abundantly available low rank coal helping advance the economy. **WF**

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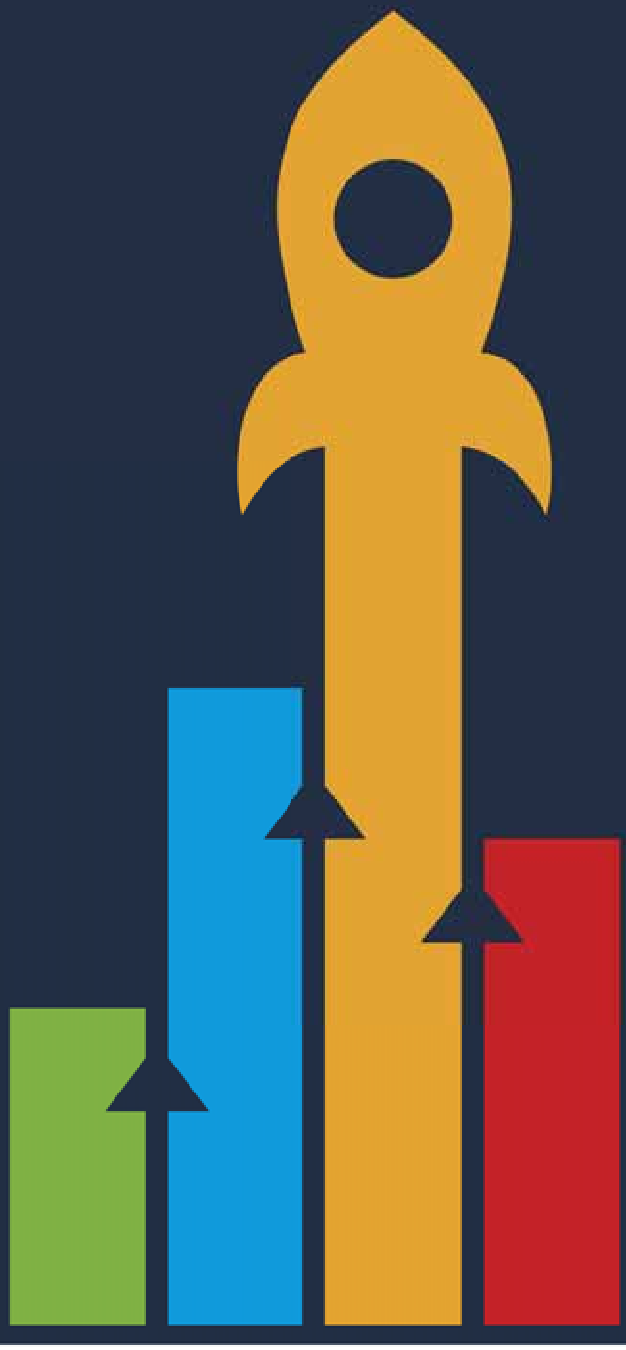

Boosting Efficiency

Steven A. Ziebold, DuPont Clean Technologies, USA, presents a solution that can improve sulfuric acid plant absorbing tower efficiencies, reducing both downtime and maintenance.

Sulfuric acid is an important large scale world chemical commodity. In the last step of the contact process, liquid sulfuric acid is made in strong acid absorbing towers. Therefore, highly efficient absorbing towers are desired for optimal performance, service life and cost. Unfortunately, part of the sulfuric acid in the absorbing tower is converted to mist, so absorbing tower installations most often use high efficiency Brownian diffusion fibre bed mist eliminators for product recovery, protection of downstream equipment and stack acid mist control.

Hanging style diffusion fibre beds have been the preferred arrangement with top element flange attachments on the clean side of the process making installation and troubleshooting easier compared to standing elements. These types of mist eliminators provide better

Figure 1. MECS® UniFlo® distributor (top) and open up-spray distributor (bottom).

performance at reduced rates when process upsets occur, and long-term when tower components wear out, resulting in higher mist levels. In addition to this, advances with diffusion fibre beds over the years have led to significant cost and energy savings.

There are, however, common problems frequently associated with liquid seals for hanging style mist eliminators. This article describes a new proven alternative that eliminates drain legs routed to trough distributors or seal leg/seal cup assemblies, thereby saving cost, plant downtime and maintenance.

Mist formation in absorbing towers

The amount of small particle sulfuric acid mist (<5 µm) and large particle sulfuric acid spray (>5 µm) formed in absorbing towers depends on several factors, such as tower design, operation, condition of equipment, gas inlet composition and gas inlet conditions. When one or more of these factors are 'out of whack' from normal design practice, a large amount of acid mist and/or acid spray can be formed in the tower.

In general, larger acid spray particles are formed by interaction of gas and liquid acid around the distributor. A portion of these large acid particles is shattered and carried upwards by the gas to mist eliminators. A significant amount of submicron mist can also be formed when a high level of sulfuric acid vapour is present and condenses from the gas phase into submicron particles. If not controlled, acid spray and mist will corrode downstream ductwork and heat exchangers, damage catalyst and cause atmospheric pollution.

Brownian diffusion fibre bed mist eliminators have been used for effective removal of sulfuric acid mist in absorbing towers since they eliminate both large acid spray particles and submicron acid mist. A tower design and operation that minimises mist and spray formation also helps mist eliminators to perform better, ensuring only clean gas goes to downstream equipment.

As a simple example of how tower design affects mist formation and ultimately downstream mist eliminator performance, Figure 1 provides a comparison of two types of distributors. The first distributor shown on the top is a MECS® UniFlo® using 'downcomers' buried into the tower packing to prevent formation of acid spray, while the second type, shown on the bottom, is an 'open' distributor spraying acid upwards to impaction plates.

The open up-spray distributor with top impaction plates generates a high level of acid spray that overloads downstream mist eliminators, resulting in re-entrainment, drip acid carry-over and high maintenance over time. A properly functioning distributor is crucial for optimal mist elimination, and DuPont Clean Technologies always recommends combining the MECS UniFlo distributor with MECS Brink® mist eliminators.

Mist collection mechanisms

Brownian diffusion fibre bed mist eliminators provide high efficiency because they are designed to use all three primary mist collection mechanisms: inertial impaction; direct interception; and Brownian diffusion. Inertial impaction and interception are the main collection methods for removing larger acid particles from process gas. However, the third mechanism, Brownian diffusion, removes submicron acid mist and is exclusively utilised by Brownian diffusion fibre beds.

All molecules in a gas stream are in constant random motion. The smaller particles pick up random motion by colliding with surrounding gas molecules. The smaller the particle, the greater the random motion and the more likely it will contact a target and be captured as it passes by collecting fibres in the gas stream. Since visible stack emissions are primarily submicron in size, high efficiency fibre beds utilising the diffusion collection mechanism are required to eliminate visible opacity.

With impaction devices, efficiency decreases as the gas and particle velocity decrease because particles have less momentum and do not deviate from the gas stream. With Brownian diffusion mist eliminators, collection of submicron particles increases as gas velocity decreases because small particles have more residence time in the collecting media to strike a target along their random path. Therefore, diffusion fibre beds are more effective in controlling mist removal during reduced plant rates.

Brownian diffusion fibre bed mist eliminators

Dr. Joe Brink developed the 'first-generation' Brownian diffusion high efficiency (HE) mist eliminator in the 1950s. This element utilises a hand-packed thick fibre bed between concentric wire mesh screens. The element can achieve high efficiencies ranging from 90 to 99.9+% depending upon the application. For strong sulfuric acid installations, chemically resistant glass fibres are used as collecting media. One concern with hand-packed fibre beds is uniformity. As a result, more fibre is used to achieve higher efficiencies compared to newer fibre bed technologies. There is also a limit with operating bed velocity and inlet mist loading which affects re-entrainment formation. Furthermore, when elements need to be repacked, bulk fibre packing is more difficult to remove compared to newer fibre bed designs.

The 'second generation' Brownian diffusion fibre bed mist eliminator called the energy saver (ES) was developed in the late

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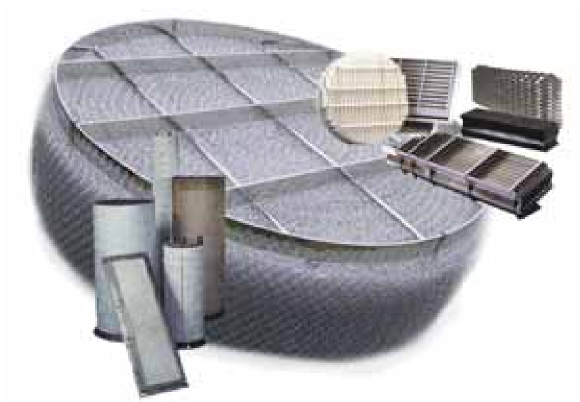

DEMISTER® mist eliminators combine high efficiency with low pressure drop in drying towers and other plant process equipment.

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Figure 2. MECS XP mist eliminators.

Figure 3. ES elements with seal legs/seal cups.

1970s and is commonly used in absorbing and heat recovery towers today. A roving fibre is wound with computer control (not hand-wrapped), resulting in exact placement of collecting fibres and a highly uniform packing distribution. Pressure monitoring during manufacture ensures exactly matched elements to optimise mist capture in multi-element installations with high efficiency. For many applications, ES diffusion fibre beds typically provide up to 20% more gas throughput compared to bulk packed elements for the same pressure drop and mist collection (or equivalent reduction in pressure drop for the same number as bulk packed elements). This is due to a more uniform wound roving packing structure along with unique wetting properties of roving fibre.

A unique feature of the MECS® ES is a bi-component fibre bed design for eliminating re-entrainment. This design utilises a proprietary drain layer of coarse fibres oriented downstream of the fine fibre collecting layer. Liquid films that would normally form and burst at the gas discharge surface of the fine fibre collecting layer are drawn into the drainage layer and drain by gravity. This allows the element to operate at higher bed velocities and inlet mist loadings compared to the original bulk-packed fibre beds that only use one fibre layer.

The 'third generation' Brownian diffusion mist eliminator (Figure 2) is a multi-layer fibre bed called the XP (eXtra Performance). The XP was developed in the mid-2000s and has been installed in many absorbing towers demonstrating up to 50% more gas throughput compared to the original hand packed elements introduced by Dr. Joe Brink in the 1950s (or equivalent pressure drop reduction using the same number of original hand packed elements). Part of the increased XP performance compared to earlier fibre bed designs has been due to development of a proprietary mat that is angle-wrapped, resulting in a highly uniform pack combined with the unique properties of fine collecting fibres.

The traditional hanging element liquid drain

The traditional hanging element 'drain' is a seal leg/seal cup design (shown in Figure 3), which has been used for over a half century in the sulfuric acid industry to remove collected sulfuric acid mist from hanging style Brownian diffusion mist eliminators. The term 'seal' is often used because this arrangement has a liquid seal allowing liquid to discharge from the inside of the element to the outside against pressure differential across the element. Collected liquid in the bottom of the element drains into the element 'seal' or 'drain' leg. The draining liquid flows into the seal cup and then overflows, resulting in large acid droplets dripping back down onto the tower packing below. Actual liquid level in the seal leg during operation is determined by operating pressure drop across the mist eliminator and the density of the liquid. Even with proper design of the element drain, this arrangement requires attention and maintenance during plant operation to ensure proper mist eliminator performance.

Consequences of failed hanging element drain

When a hanging element drain is blocked, collected liquid in the bottom of the element rises and tries to drain back through the fibre bed against the gas flow. The collecting fibres become saturated and gas flowing through the fibre bed creates bubbles at the liquid level/fibre bed interface, which, in turn, generates small acid particles by film shatter. Acid particles several microns in diameter are then carried downstream by the gas exiting the mist eliminators, exposing downstream equipment to drip acid, resulting in corrosion and maintenance.

Another serious operating condition occurs when a drain seal fails, resulting in gas bypassing an element flowing upwards through a 'blown' seal leg. Gas bypassing through an element seal leg prevents liquid collecting in the bottom of the element from draining down through the seal leg. A large amount of re-entrainment is formed by gas vertically discharging though the bottom element drain coupling and consequently shearing collected liquid in the bottom of the element into small particles that are carried downstream (Figure 4).

Alternative to traditional hanging element drains

The AutoDrain™ (AD) option for hanging style MECS Brink mist eliminators is currently in service in many absorbing tower installations. AD effectively drains acid from mist eliminators without the use of expensive drain legs/seal cups or complex

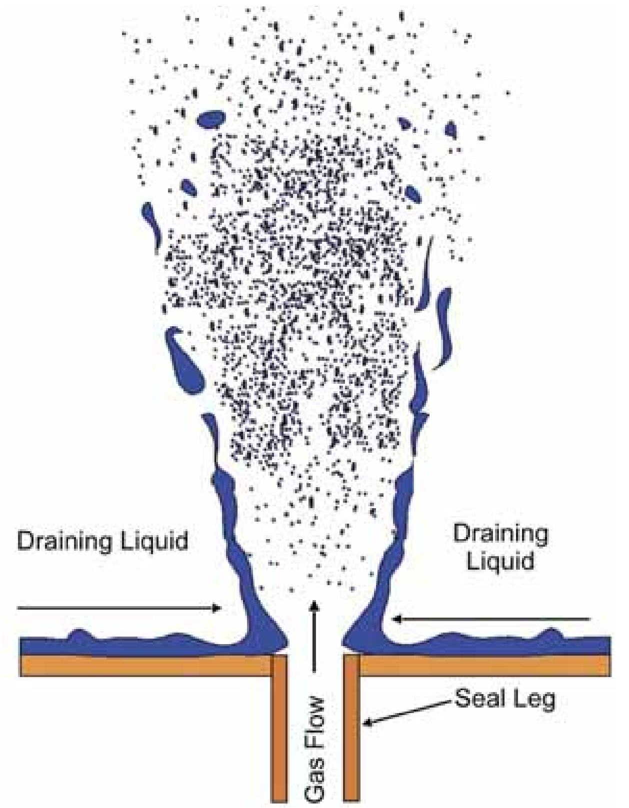


Figure 4. Close up illustration of 'blown' seal leg in bottom of hanging mist eliminator.

drain leg piping systems routed to MECS UniFlo distributors. AD eliminates the hazard of working in acid resistant apparel required when attaching drain legs to hanging elements below the tube sheet, which is a very dangerous work area. When elements are removed from a tower, this same hazardous work must be performed to detach drain legs before they can be lifted out. AD prevents this hazard as well.

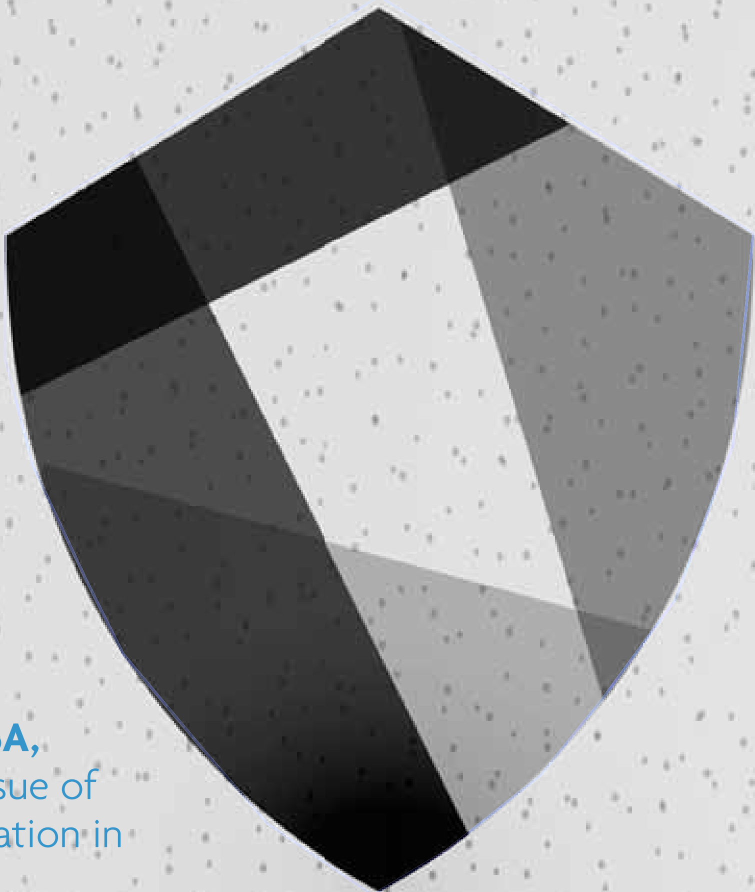
AD eliminates element seal legs directly routed to trough distributors or seal leg/seal cup assemblies, which are the more frequent maintenance trouble spots in the tower and one of the more difficult areas to troubleshoot. Also, when maintenance is required on tower acid distributors, hanging drain legs (pipes) from the mist eliminators are a significant obstruction to anyone working in acid resistant apparel, which can result in falls and injury. AD averts this safety hazard as a set of mist eliminators built with AD does away with all the hanging drain legs or seal legs/seal cups and so presents significantly fewer obstructions under the mist eliminators, which leads to easier and safer maintenance on tower components.

During operation using AD, the inside bottom element plates will typically be dry, while bottom plates of standard elements with traditional drains will typically have accumulated liquid agitated by gas near drain couplings, resulting in re-entrainment formation. Thus, elements using AD reduce re-entrainment formation on the clean gas discharge side leading to increased protection of downstream equipment.

Conclusion

Increased sulfuric acid plant efficiencies can be realised by operating state-of-the-art absorbing towers that minimise mist formation in combination with high performing fibre bed mist eliminators. This will boost plant efficiency over time, leading to significant cost and energy savings. WF

PROTECTING PUMP TANKS



Skip Unger, Acid Piping, USA, discusses the issue of weak acid formation in pump tanks.

A common problem today in sulfuric acid production plants is weak acid formation in sulfuric acid pump tanks. A strong indicator that weak acid is forming is typically apparent on anything installed at the liquid level. Weakened acid will have a lower specific gravity and will float on the strong acid. This weakened acid, particularly at the higher temperature of the pump tank, will be highly corrosive to metals it contacts, such as dip pipes, acid return lines, dilution pipes, bubbler pipes and pumps. This is usually evidenced by 'hour-glassing' or a necking down of material at the acid liquid level interface. If weak acid is present, it will have a significant impact, increasing the corrosion to the components and greatly shortening the life of this equipment. With an alloy pump tank, this can be

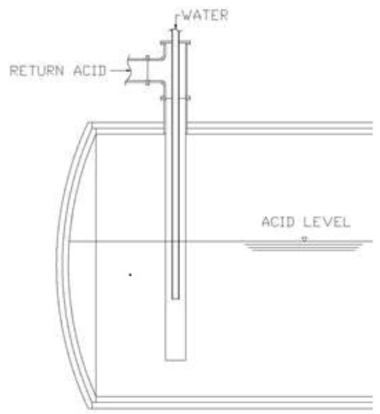


Figure 1. Typical or common sulfuric dilution system.

Figure 2. Indication of 'hour-glassing' or 'necking down'.

Figure 3. Example of weak acid attack at liquid level with iron sulfate formation.

Figure 4. Iron sulfate formation inside pump's shaft column.

increasingly alarming, as most alloy tanks are of the high-silicon stainless alloys that have limited corrosion resistance in weakened sulfuric acid.

Causes of weak acid formation

Sulfuric acid has an affinity for water. Weakened acid has a lower specific gravity than strong concentrated acid. Therefore, any improper mixing or introduction of moisture into the pump tank will cause this weakened sulfuric acid to float on the surface of the stronger, concentrated sulfuric acid in the pump tank.

Sulfuric acid dilution systems

Dilution systems are the first obvious suspect to be checked, but are often overlooked, particularly if they are installed in the pump tank. Dilution systems should be inspected at every turnaround or plant shutdown for repairs. A common dilution system within a pump tank utilises a tee or bossed elbow mounted above the pump tank and an acid return pipe extending down into the pump tank below the normal liquid levels. Usually installed in this return pipe is a smaller pipe for the purpose of injecting the dilution medium that is mounted to the top of the tee or the boss on the elbow. This smaller pipe, often referred to as a stinger, dilution quill or dilution pipe, is used to inject the dilution medium, such as water or weak acid, into the acid stream returning from the absorbing tower (see Figure 1).

Compromised acid return pipes or dilution pipes that might be 'holed out' may allow unmixed, weakened acid onto the surface where it will 'float' on the stronger acid due to the lower specific gravity, thus subjecting anything at the liquid level, including these already compromised dilution parts, to even more accelerated corrosion. Vertical submerged pumps also see this increased corrosion at the normal liquid operating levels whose expected life can be significantly shortened. An example of this hour-glassing or necking down can be seen in Figures 2 and 3.

Pump tanks under negative pressure

In many cases, plant operators have installed venting lines from the pump tanks to the suction inlet on drying towers to capture fugitive emissions (free SO_3) from the pump tank. In many cases, these venting systems were not in the original plant design and have been added over the years to help minimise total plant emissions. This has been done in many ways and using a wide variety of materials. If a plant has this type of venting system installed, it should be reviewed in the following ways. Depending on the amount of vacuum the pump tank may see, it is advisable to have a control valve at the connection of the vent line to the pump tank. This valve can be completely closed and then slowly opened until the wisp of SO_3 is no longer apparent at the pump tank vent. SO_3 will create a plume of smoke when it reacts with the humidity in the air. Keeping this vacuum to a minimum will minimise the ingress of moisture-laden atmospheric air into the pump tank.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Since sulfuric acid has an affinity for water, the moisture in the air will interact with the sulfuric acid, causing a weak acid layer to form on the surface and thus causing the increased corrosion of components at the liquid level, including an acid dilution system if there is one in the sulfuric acid pump tank. This can exaggerate the problem if it prematurely corrodes the dilution system components due to the weakened acid layer on the surface.

Another benefit of this action is that it may reduce the amount of moist air entering a vertical submerged pump's stuffing box if the pump tank is so equipped. Often, iron sulfate can form inside the pump's shaft column to the extent that it can damage or significantly impact the acid circulating pump(s). Reducing the vacuum to the bare minimum and at the same time utilising the pump's lantern ring connection on the stuffing box to introduce a positive pressure of instrument air into the stuffing box will help to eliminate these issues (see Figure 4).

Conclusion

Indications of increased corrosion of components installed in contact with the liquid level in a sulfuric acid pump tank are indicators that weak acid has formed on the surface of the sulfuric acid as indicated in Figures 2 – 3. This can be attributed to a faulty dilution system or the acid circulating pump tank being under vacuum (or possibly both).

Excessive iron sulfate formation inside the pump shaft column is also an indicator of moist air entering through the pump stuffing box into a pump tank under vacuum or negative pressure (see Figure 4).

It is also worth noting that alloy pump tanks are very susceptible to corrosion at the liquid level if weak acid is present at the liquid surface. These alloy pump tanks are most often constructed of high-silicon stainless steels. These alloys work very well in normal concentrated acid conditions, but lose their effective corrosion resistance when subjected to weakened sulfuric acid as all passivation is lost.

Corrective actions

The entire acid dilution system, if installed in the pump tank, should be checked whenever acid circulating pumps are pulled for normal maintenance to make certain all components are intact with the expected wall thickness and/or integrity to last to the next scheduled shutdown.

If the sulfuric acid pump tank has a venting system creating a negative pressure in the pump tank, a control valve should be installed in this vent line at entry into the tank to minimise the amount of vacuum on the pump tank to the bare minimum. This system should also be checked as part of your regular preventative maintenance to verify the valve is correctly set and properly operating.

The pump's stuffing box should be equipped with a tap connection on the stuffing box for injecting dry instrument air through a lantern ring. This should be installed at a pressure of 3 – 5 psi over the tank pressure at a flowrate of 3 – 5 ft^3/min. This system should be maintained as part of normal preventative maintenance. It should also be known that the instrument air flowrate should be continuous even in an installed, idle, spare pump. WF

A Vertical Approach

Benoît Martin, Sulzer, Belgium, explains how vertical turbine pump design can improve operating performance in sulfuric acid production plants and open new paths for process development.

Sulfuric acid is one of the most important industrial chemicals as it is used in various process applications, such as fertilizers, metals, pigments, explosives, and several others.

The production of sulfuric acid is achieved through several steps. At first, liquid sulfur is burned in a furnace to produce sulfur dioxide (SO_2). In this first phase, it is of primary importance to avoid humidity, which would lead to catastrophic corrosive conditions. The produced SO_2 gas is then processed by high temperature catalytic oxidation to generate sulfur trioxide (SO_3), which will be used in a contact process to produce sulfuric acid.

In a conventional contact phase process, depending on the installation, the concentration unit features absorption and drying towers, where an ascending stream of gas flows through a sprayed cloud of concentrated sulfuric acid. In the absorption tower, SO_3 reacts with H_2SO_4 and leads to a higher concentration of sulfuric acid, which is then diluted by the addition of water. This process requires

Figure 1. Standard vertically-mounted end suction pump.

Figure 2. Standard vertical turbine pump.

continuous pumping of sulfuric acid from a tank to the tower. The principle of the drying tower is similar, but it uses ambient air instead of SO_3 gas. It is an important operation since sulfuric acid droplets capture the humidity of air so that the dried air is then suitable to be injected into the sulfur burning furnace.

In most configurations, vertical pumps are installed at the top of a tank, ensuring maximum safety and reliability. This lay-out does not require the connection of the pump to the tank under the liquid level, and any leakage that may occur will be contained. Additionally, it ensures safer on-site installation and maintenance because those operations are performed above the tank.

The typical operating parameters for circulation pumps used in the above application are as follows:

- Liquid: H_2SO_4.
- Concentration: 92 – 99.9%.
- Temperature: 60 – 120˚C (158 – 248˚F).
- Flow: up to 1800 m^3/hr (7800 gal./min.).
- Head: 15 – 30 m (49 – 99 ft).

More stringent conditions could be managed with an alternative process design. Due to exothermic reactions, the global heat generated in the process is important. The common plant design uses this energy to generate low temperature steam, which is then transformed into electricity. Process licensors have developed heat recovery systems allowing the production of higher temperature steam, which is more efficient in electricity production. This is achieved by using a similar tower working at a much higher temperature than in the conventional process.

The typical operating parameters for heat recovery circulation pumps used in the above application are as follows:

- Liquid: H_2SO_4.
- Concentration: 99.9%.
- Temperature: 200 – 250˚C (392 – 482˚F).

Challenge

Sulfuric acid is highly corrosive, and a variation of concentration or temperature could increase corrosion drastically, resulting in considerable damage to the plant equipment. The challenge for operators is to keep those parameters under control, and this is more difficult to achieve during transient phases (i.e. starting, shutoff, surge, etc.) than other phases. For that reason, equipment lifetime and reliability are some of the most important factors to limit the number of those difficult phases and related risks.

Considering pump operation, the two main concerns would be material corrosion and mechanical issues. Mechanical issues (i.e. bearing lifetime, wear part consumption) are the same for corrosive applications and non-corrosive applications, while both are not totally independent since corrosion could affect the geometry of parts and have subsequent effects increasing mechanical issues. In the worst conditions, it could turn into an exponential phenomenon with catastrophic damage to the pump. The challenge for pump manufacturers is to select a design that shows the best performance in those conditions.

Design assessment

In the present case, the two main primary characteristics to define the pump design are the material of construction and the pump type itself.

The material selection requires good metallurgical and process knowledge since the corrosiveness of sulfuric acid varies greatly depending on the concentration and temperature. High concentration 99% sulfuric acid at a medium temperature of 70˚C may be pumped with a pump made of acid-proof cast iron materials, while reducing to a lower concentration below 94% may require a higher-grade alloy.

Material performance may be assessed with corrosion rates available in literature. On the other hand, it could be difficult to find similar operating conditions that correspond to the actual plant operating conditions. Consequently, material selection is achieved through a complex process based on academic research, laboratory testing and, most importantly, the field experience of users and the manufacturer.

Meanwhile, most data or field tests are available for static conditions only. Knowing that flow velocity has an impact on erosion, the corrosion rate of the material eventually varies. In some cases, a material with the lowest corrosion rate in static conditions has shown a higher corrosion rate in dynamic conditions.

Considering the observation above, the challenge is then to select the vertical pump design that gives the best intrinsic performance independently of material selection. The two main designs that are available for vertical pumping out of a tank are a vertically-mounted end suction pump (Figure 1) or a vertical turbine pump (Figure 2).

The first one is the most common for these applications to date. It features a volute case installed on a suspension column with a separate discharge pipe rising up to a baseplate. The volute case geometry generates radial thrust on the pump line shaft. The thrust leads to deflection and vibrations and causes wear of the pump bush bearing and the roller bearings. As previously mentioned, the highly corrosive conditions, where the clearance increases over time, further deteriorates the mechanical condition of the pump. This effect being exponential, the equipment lifetime is consequently rapidly decreased.

In a vertical turbine pump, the medium is pumped directly through the impeller from the suction to the column and discharge head. The symmetric diffusor case (Figure 3) of the pump distributes the thrust equally. Detrimental thrust on the line shaft does not occur and, as a result, the level of vibrations and the shaft deflection can be kept at a minimum. This advantage does not only apply to the best efficiency point of the pump, but to the entire flow range.

A radial thrust comparison (Figure 4) clearly shows the radial thrust variation depending on the case design. A single volute shows the worst impact. In all cases, a vertical turbine pump design keeps radial thrust at the lowest value, further preventing mechanical damage to the pump.

In the presence of a high temperature, the vertical turbine pump design with only the discharge column filled with liquid does not present a risk of stress due to the differential thermal expansion of an asymmetric construction with the suspension column partially filled with liquid.

Another aspect to be considered is the localised observed corrosion at the acid/gas interface. It is the result of localised liquid concentration and temperature. Devastating consequences could arise due to that phenomenon. Good plant maintenance practice requires metal thickness measurements to monitor the condition of the parts and ensure their replacement in due time if necessary. A vertically-mounted pump features four interfaces (i.e. two on the support column, one on the shaft and one on the discharge pipe), while a vertical turbine pump only has one interface on the discharge column. This limits corrosion, making monitoring easier and ultimately reducing the risk of catastrophic failure significantly.

The compact design of a vertical turbine pump provides additional benefits for installation and maintenance. Discharge through a column and sump head requires a footprint dimension that is less than half of that needed by a volute case design. A side discharge on the sump head can be flanged directly to a downstream discharge pipe. Additionally, pump assembly is much easier with only one column assembly.

Figure 3. Symmetric diffusor case.

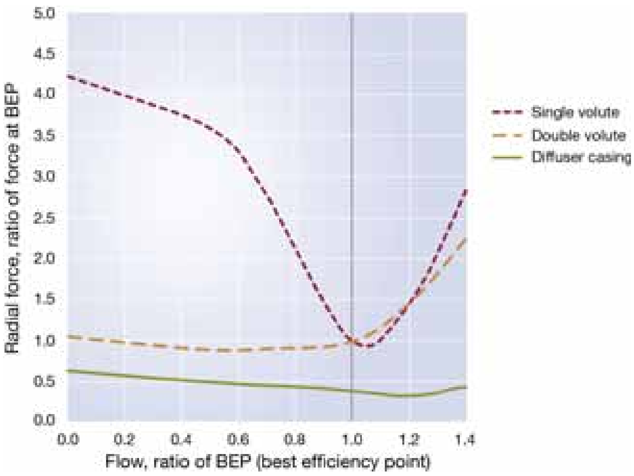

Figure 4. Radial thrust comparison.

As a result of this assessment, pump type VAS (Figure 5) has been designed combining all advantages of the vertical turbine pump with adequate material selection and technical adjustments adapted to the specific requirements of the process. It benefits from all experience accumulated while developing and manufacturing heavy duty equipment for demanding applications.

The current range performance covers flowrates up to 4000 m^3/hr, and higher flowrates could be considered based on extended standard vertical turbine pump flow range (Figure 6). The standard construction is suitable for absorption tower and drying tower circulation, and operation in a heat recovery system requires specific features to ensure safe operation at higher temperatures.

Vertical turbine pumps for sulfuric acid have been in operation in numerous plants worldwide for decades, showing high performance achievements. Depending on the operating conditions of the plant, the overall lifetime of the pumps has been up to more than eight years with no maintenance required. Furthermore, the design has allowed process improvement as illustrated in recent projects.

Figure 5. Vertical sulfuric acid pump type VAS.

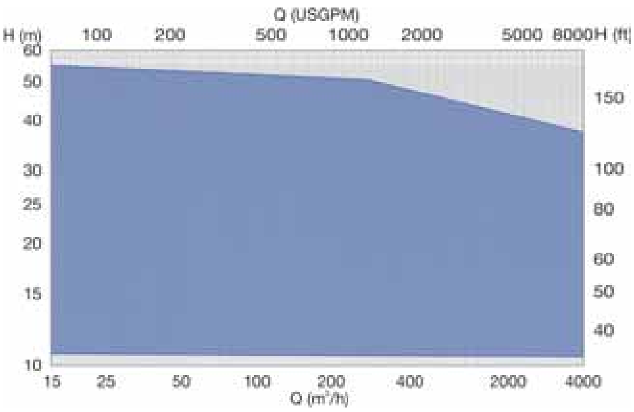

Figure 6. VAS performance range.

Figure 7. 2800 m^3/hr VAS pump on the test bench.

Case study 1

A leading global fertilizer producer was facing difficulties in optimising the operation in one of its sulfuric acid plants because of limited pumping equipment lifetime and increased process downtime. The equipment involved was a circulation pump in a heat recovery system. The lifetime of the pump originally supplied with the system was less than one year and consequently far out of plant standards. Being the sole installed running pump, troubleshooting of the pump required system shutdown.

As a satisfied user of VAS pumps for decades, the plant team contacted Sulzer's technical department to discuss the problem faced with a competitor's equipment. Sulzer has since helped to increase the equipment lifetime slightly. Meanwhile, problems due to radial thrust, which were clearly visible on damaged parts, were intrinsic to the volute case design.

The existing pump was eventually replaced by a vertical turbine pump design, which has now demonstrated more than a double lifetime compared to the previous equipment at the customer's site. The pump is still running to date, so the customer is now planning to extend the operating period between system shutdowns.

Case study 2

A current development trend for designing sulfuric acid plants requires an increase in the pump flow. The largest existing plant currently in operation features a continuous circulation of two pumps with a typical flow between 1200 m^3/hr and 1800 m^3/hr. An engineering company identified the benefits of operating a single pump designed for the total capacity (i.e. tank lay-out, single downstream line, etc.). The initial requirement considered a single pump in operation with a flowrate of 2600 m^3/hr.

To cope with this significant performance increase, the equipment size should be much larger, amplifying the disadvantage of a vertically-mounted end suction pump. Due to the asymmetric volute case design, the radial thrust value and thermal stress would have more than a significant impact, drastically limiting the equipment lifetime. On the other hand, a vertical turbine pump does not present those technical issues, whichever the equipment size. Considering those benefits, the project has proceeded with a single pump for a sulfuric acid flow of 2800 m^3/hr.

Additionally, a compact design avoids oversizing the equipment and allows for easy maintenance and installation as demonstrated on the test bench during the manufacturing process (Figure 7).

Conclusion

The vertical turbine pump technology specifically designed for sulfuric acid applications improves operation performance even in the most stringent conditions.

The pump design extends the lifetime of the equipment and allows the operators to increase the mean time between maintenance (MTBM) significantly. The compact construction of the vertical turbine pump enables easy installation and maintenance-friendly operation. The symmetric diffusor case design allows the development of bigger pumps for higher sulfuric acid circulation flows than what is possible with existing equipment. This opens new paths for process development. WF

IN THE PROCESS

Since the first urea technology developments, multiple challenges, such as efficient handling of unconverted material, process efficiency and energy saving, have been urging urea technology licensors to continuously develop the technology.

The main targets of development have become optimisation of operating conditions, simpler equipment layout, high equipment reliability, high product quality, emission control and establishment of large scale urea plants.

To answer such challenges, TOYO has established the ACES21® urea process and spout-fluid bed urea granulation process. Their features will be described in this paper.

Features of the urea process

TOYO has developed ACES21,[1] which saves energy and reduces plant cost without sacrificing the performance and efficiency of the urea plant. ACES21 has been developed together with P.T. Pupuk Sriwidjaja Palembang (PUSRI) of Indonesia as a further cost and energy saving version of the ACES (Advanced Process For Cost And Energy Saving) process.

Since the success of the first ACES21 plant of Sichuan Chemical Works (Group) Ltd (SCW) in 2004, TOYO has been awarded a total of 13 ACES21 projects, including a 4000 tpd plant for Indorama Eleme Fertilizer and Chemicals Ltd (IEFCL), which became the world's largest single train urea plant (Figure 1).

Baharuddin Maghfuri, Toyo Engineering Corp., Japan, discusses the key features of new urea and granulation processes.

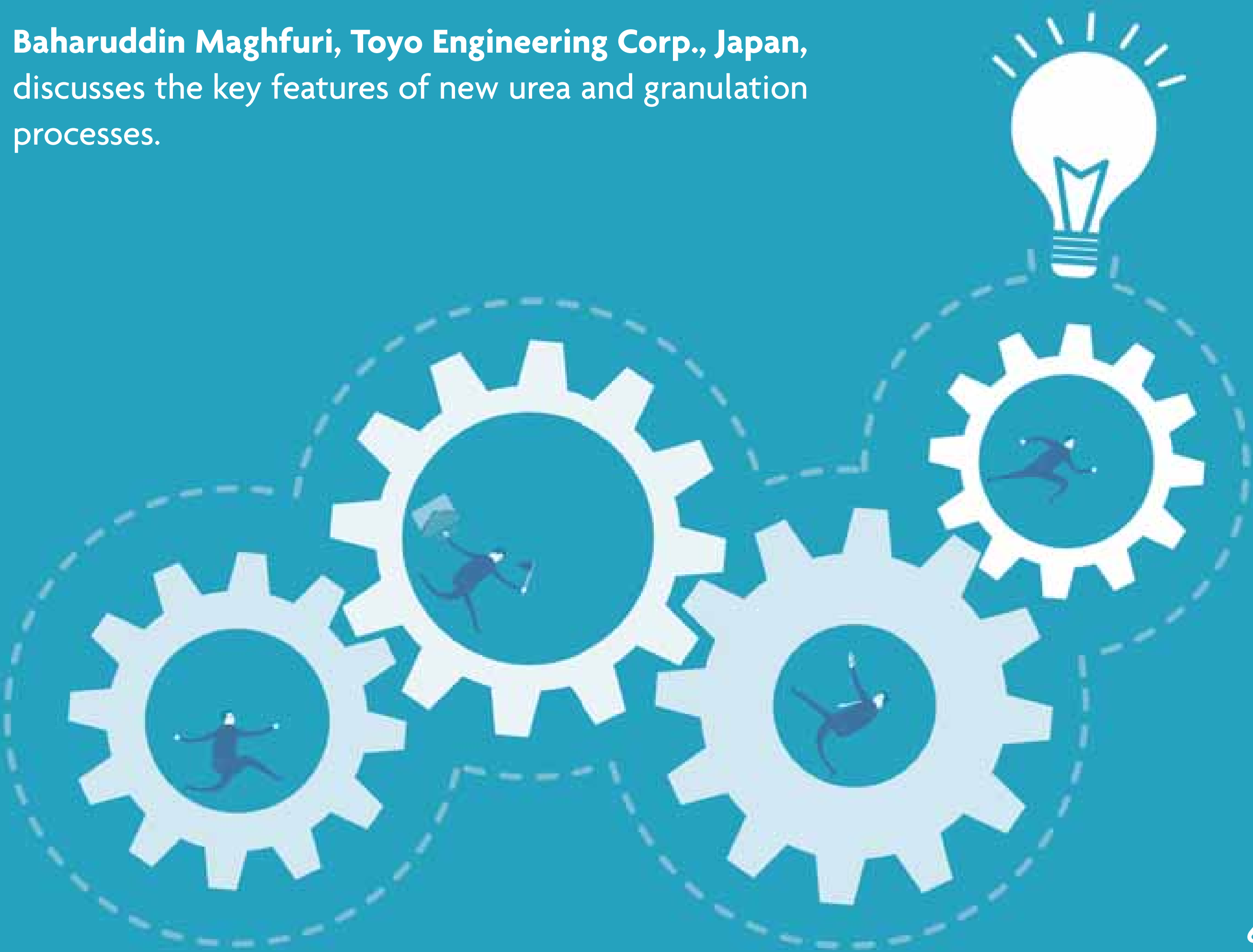

Figure 1. IEFCL urea plant (4000 tpd) in Nigeria.

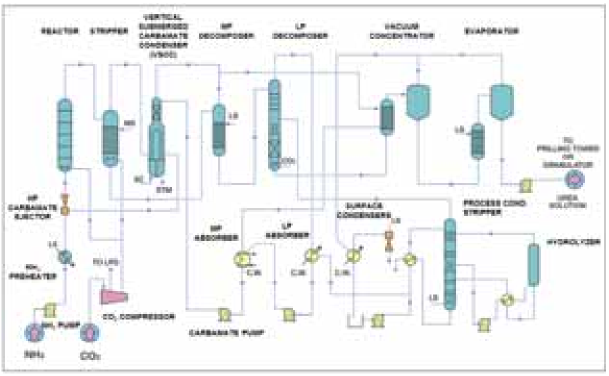

Figure 2. Flow diagram of the ACES21® urea process.

Table 1. Typical utility in TOYO's granulation plant

Steam	0.01 t/t
Power	23 kWh/t
Cooling water	Nil

Table 2. Emissions guidelines for urea dust and ammonia in urea plants

World Bank guideline[2]	Urea dust: 50 mg/Nm^3
	Ammonia: 50 mg/Nm^3
EFMA guideline[3]	Urea dust: 50 mg/Nm^3
	Ammonia: 50 mg/Nm^3

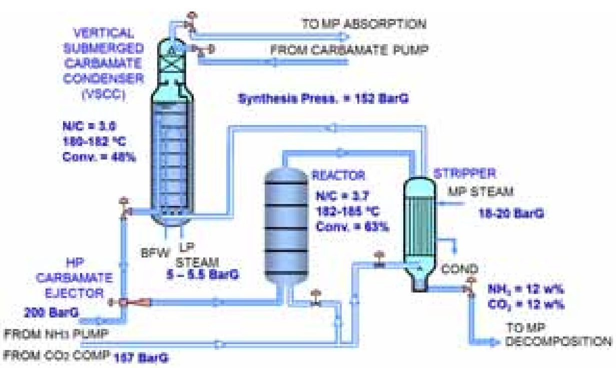

Figure 3. ACES21 synthesis section.

Figure 2 shows a typical process flow diagram for an ACES21 urea plant, whilst Figure 3 shows a schematic flow sheet of the ACES21 synthesis section. The ACES21 process synthesis section consists of a reactor, a stripper and a carbamate condenser. Liquid ammonia is fed to the reactor via a high pressure carbamate ejector, which provides the driving force for circulation in the synthesis loop instead of gravity as for the original ACES process. The reactor is operated at an N/C ratio of 3.7, 182 – 184°C and 152 barG. The CO_2 conversion to urea is as high as 63 – 64% at the exit of the reactor. Urea synthesis solution leaving the reactor is fed to the stripper where unconverted carbamate is thermally decomposed and excess ammonia and CO_2 are efficiently separated by CO_2 stripping. Stripped urea solution is sent to the MP decomposition stage to be purified further. The stripped off gas from the stripper is fed to a vertical submerged carbamate condenser (VSCC), operated at an N/C ratio of 3.0, 180 – 182°C and 152 barG. Ammonia and CO_2 gas condenses to form ammonium carbamate and subsequently urea is formed by dehydration of the carbamate in the shell side. Reaction heat from carbamate formation is recovered to generate 5 barG steam in the tube side. A packed bed is provided at the top of the VSCC to absorb uncondensed ammonia and CO_2 gas into recycled carbamate solution from the MP absorption stage. Inert gas from the top of the packed bed is sent to the MP absorption stage.

Major features of ACES21, which contribute to low investment cost and low energy consumption for urea production, are summarised below.

Ground level reactor

In CO_2 stripping technology, the reactor – the largest and heaviest vessel in the urea plant – is normally installed at a 20 – 22 m level in order to feed urea synthesis solution to the stripper by gravity. If the reactor is installed at ground level, civil and erection costs can be greatly reduced. TOYO and PUSRI have jointly developed the ACES21 process, aiming to install the reactor at ground level, maintaining the advantages of CO_2 stripping technology. The two-stage synthesis concept employing a VSCC and a high pressure ejector enables the high pressure equipment in the synthesis section to be laid out compactly in low elevation. Depending on the plant's capacity and configuration, the highest level (the VSCC top) is approximately 30 – 35 m, which is significantly lower than even the traditional solution recycle process in which the reactor is installed on the ground.

Vertical submerged carbamate condenser

Figure 4 illustrates a configuration of the VSCC, which condenses NH_3 and CO_2 gas from the stripper to form ammonium carbamate and synthesises urea by dehydration of ammonium carbamate in the shell side, and removes the reaction heat of ammonium carbamate formation by generating 5 bar steam in boiler tubes.

The advantages of the vertical submerged configuration of the carbamate condenser are summarised as follows:

- High gas velocity, appropriate gas hold up and sufficient liquid depth in the bubble column promote mass and heater transfer.

- An appropriate number of baffle plates distribute gas bubbles in the column effectively without pressure loss.
- A vertical design allows a smaller plot area.

Optimum selection of synthesis condition

Figure 5 shows CO_2 conversion and equilibrium pressure versus N/C. In the ACES21 process, the VSCC is operated at an N/C ratio of 3.0, which allows relatively high temperature operation of the VSCC, rendering efficient heat transfer between the shell and the tube and higher reaction rate of ammonium carbamate dehydration to form urea. The reactor N/C ratio is selected at approximately 3.7 to maximise CO_2 conversion with appropriate excess pressure. As a result, a high CO_2 conversion of 63 – 64% is achieved in the reactor at relatively low temperature and pressure (i.e. 182°C and 152 bar).

Less corrosion

TOYO and Nippon Steel & Sumitomo Metal Corp. (NSSMC) have jointly developed duplex stainless steel DP28W™ for urea plants. The biggest advantage of duplex stainless steel is the excellent corrosion resistance and passivation property in urea-carbamate solution, which enhances reliability of equipment and enables a reduction of the passivation air. In addition, DP28W has high mechanical strength, which drastically reduces the thickness of the high pressure section components.

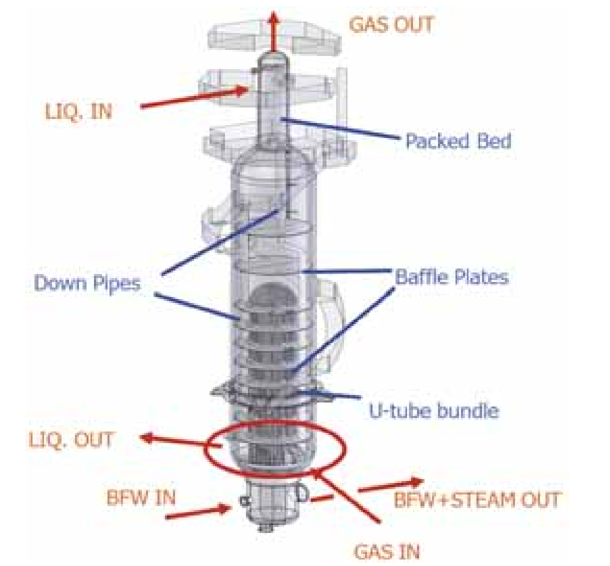

Figure 4. Configuration of VSCC.

Clean effluents

The liquid effluents from the urea plant contaminated with NH_3, CO_2 and urea are processed in the process condensate stripper-urea hydrolyser system. The process condensate leaving the system is purified to 1 ppm of urea and 1 ppm of NH_3. The exhaust air from the prilling tower (or granulator) is scrubbed through a packed bed scrubber to reduce the urea dust content to 30 mg/Nm^3 of air.

Table 3. Schemes of scrubbing technologies

Scheme	Water scrubbing	Option one. Single stage acid scrubbing	Option two. Double stage acid scrubbing	Option three. Acid scrubbing without by-product (ammonium salt)
TOYO's experiences	43 plants	Three plants	Four plants	One plant
Required acid (98% H_2SO_4)	None	1 kg/t urea	1 kg/t urea	1 kg/t urea
By-product	None	45% urea ammonium salt solution: 90 kg/t urea	40% ammonium salt solution: 5 kg/t urea	None
Urea product	Urea	Urea	Urea	Urea + ammonium salt (0.2 wt%)
Recovery of urea dust	As urea product	As by-product	As urea product	As urea product
Recovery of ammonia	None	As by-product	As by-product	As urea product
Urea dust emission	‹30 mg/Nm^3	‹30 mg/Nm^3	‹30 mg/Nm^3	‹30 mg/Nm^3
Ammonia emission	Ammonia in urea melt is emitted	‹30 mg/Nm^3	‹30 mg/Nm^3	‹30 mg/Nm^3

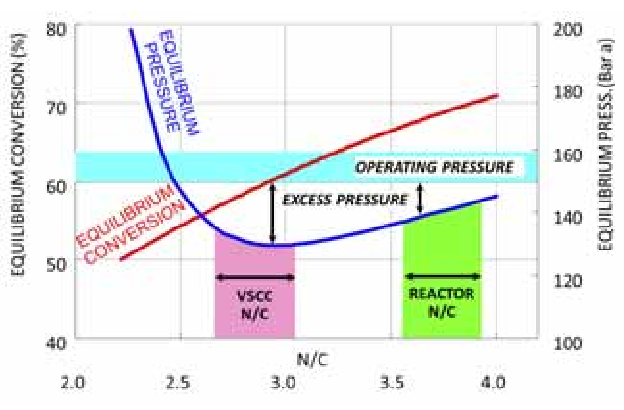

Figure 5. Equilibrium conversion and equilibrium pressure versus N/C.

Figure 6. Granulation unit at the IEFCL urea plant (4000 tpd) in Nigeria.

Features of the granulation process

TOYO's spout-fluid bed urea granulation process, which produces large sized, high quality urea product whilst saving as much energy as possible, is one of the company's several urea process technologies. It has been applied for 23 urea plants ranging between 50 tpd and 4000 tpd, and is a proven and reliable process. Figure 6 shows the granulation unit at the IEFCL urea plant (4000 tpd) in Nigeria, the world's largest single train granulation unit.

TOYO started developing a urea granulation process based on a spouted bed type urea granulator, and expanded its own technical range to provide a variety of urea fertilizer products in addition to the conventional urea prill product and urea solution product. In the late 1990s, TOYO further improved its design of the granulator by applying spout-fluid beds, which combine the spouted beds and fluidised beds, and reduce energy requirements whilst improving the quality of the product granules.

Figure 7 illustrates the process flow of TOYO's granulation process. The urea solution or molten urea is fed on the spouting urea seeds through the multi-spray nozzles to enlarge the recycle particles (seeds) in the granulator. The water in the feed urea solution is evaporated by spouting air on the spouted beds in the granulator to produce the urea granules. The enlarged granules are cooled to a suitable temperature by the cooling function of fluidising air on the internal fluidised beds in the granulator.

Coarse urea granules produced in the granulator are screened to separate the product size granules from over and under sized granules through the double deck screen. Small sized granules are recycled back to the granulator as the seed and over sized granules are crushed through the double roller type crusher and recycled back to the granulator together with the under sized granules as the seeds.

Exhaust air from the granulator and cooler is scrubbed in the wet type dust scrubber to recover the urea dusts in the exhaust air. Recovered urea dusts through the dust scrubber are recycled back to the urea plant for the recovery.

Major advantages of TOYO's granulation process are presented as follows.

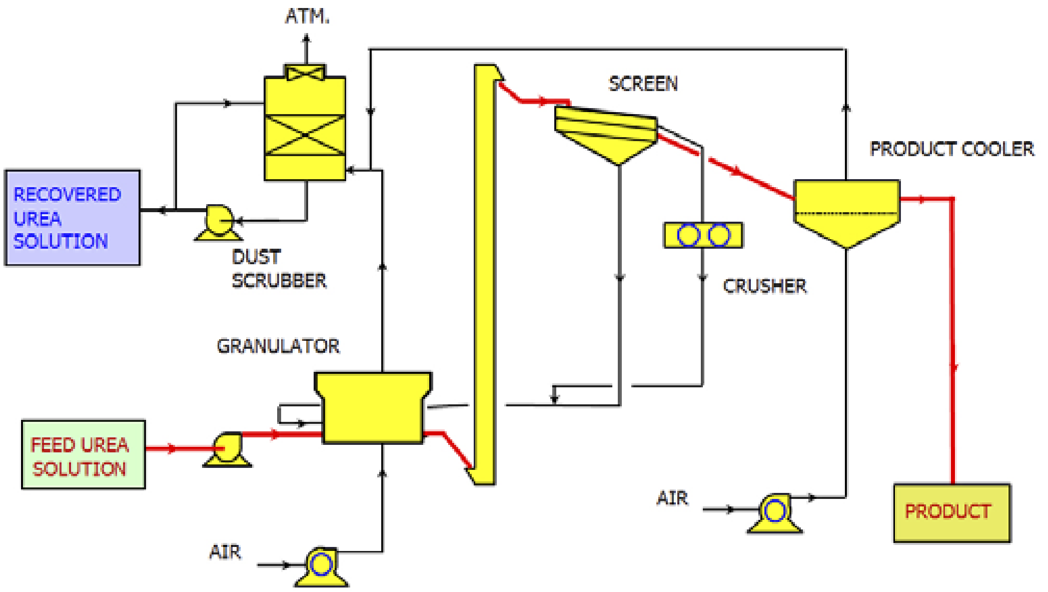

Figure 7. Process flow of TOYO's granulation process.

Efficient granulation mechanism at spout-fluid bed granulator

Figure 8 illustrates a schematic of the spout-fluid bed granulator. In the granulator, the spouted bed is formed by an upward stream of air introduced into the bottom of the granulator, and the fluidised bed is formed surrounding the spouted beds.

The air introduced into the spouted bed maintains that the particles remain in suspension. The droplets of urea solution fed to the bed through the spray nozzles are deposited on the surfaces of seed particles. Thus the particles gradually grow layer-upon-layer.

Since air introduced for spouting and fluidising has effects on cooling and drying, the spout-fluid bed granulator has functions of a cooler and a drier, respectively. Thanks to the excellent drying function, product with a moisture content of 0.3% or less can be obtained even with 96% urea solution feed. Lower concentration of urea solution feed contributes to lower biuret product and lower utility requirement in the granulation plant than molten urea feeding case.

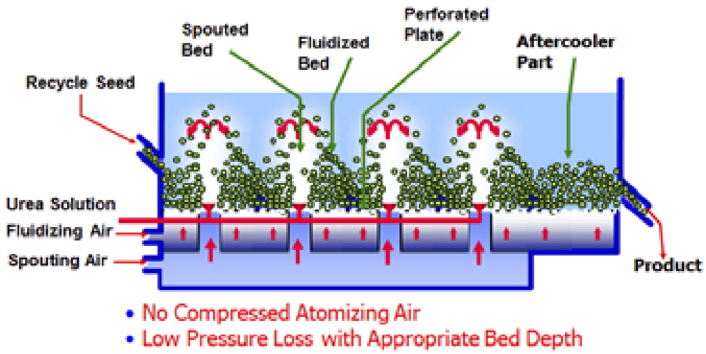

Figure 8. Illustration for spout-fluid bed.

High energy efficiency

Almost all energy for the granulation process is consumed as the power normally for air fan, blower, pump and the transportation equipment. Figure 9 shows the breakdown of power consumption for each user in the urea granulation plant. 80% of total power is consumed for the air fan and blower. Therefore, reducing the power consumption for the air fan and blower is the most important point for energy saving.

TOYO has succeeded in minimising the head and flow rate of the air fan and blower by the following features:

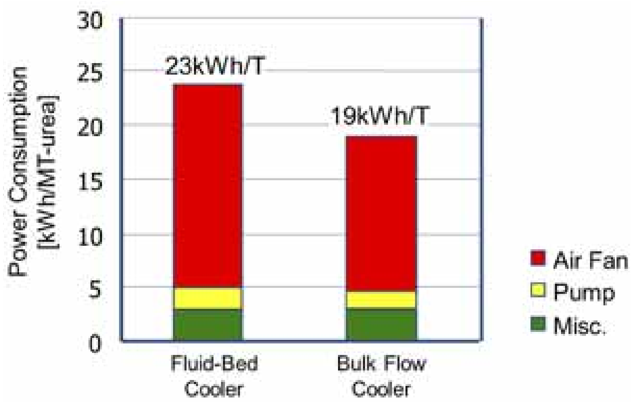

Figure 9. Typical power consumption in TOYO's granulation plant.

- No compressed air for atomisation – the urea granulation process utilises a single (liquid) phase spray nozzle with spouting air. The compressed air for atomisation is not required. The lower pressure drop for spouting air saves power for the blower.
- Optimal bed depth minimises pressure loss in the granulator – the combination of a spouted bed and a fluid bed is a feature of TOYO's urea granulation process. The solution is sprayed in the spouted bed and the fluid bed has the functions of conveying and cooling the particles. It is not necessary to keep a high level for the fluid bed, which leads to lower power consumption by the fluidising air blower.
- Smaller pressure drop dust scrubber – the packed bed type dust scrubber designed by TOYO realises

Figure 10. TOYO's conventional spray nozzle (left) and new type multi-spray nozzle (right).

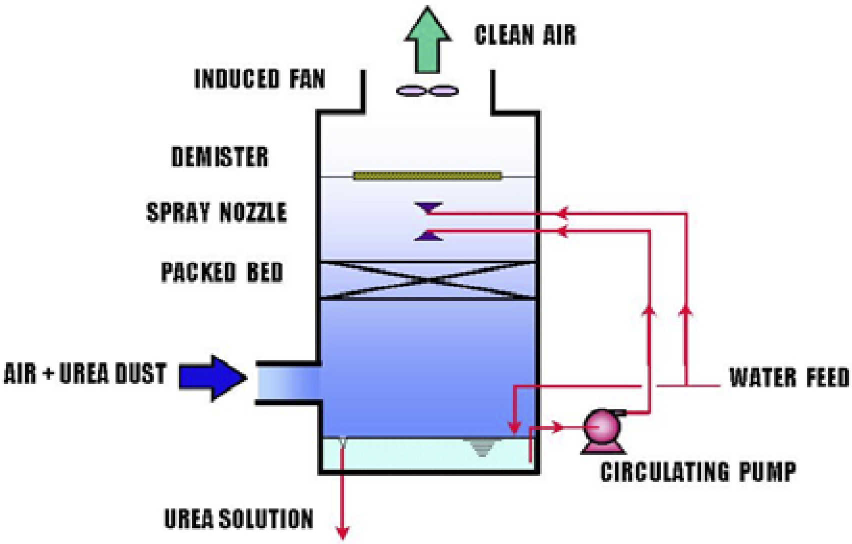

Figure 11. Dust scubber (water scrubbing scheme).

both the low pressure drop and the high efficiency for dust reduction. The low pressure drop through the dust scrubber leads to lower power consumption by the induced fan.

Table 1 shows the typical energy consumption of TOYO's urea granulation process.

When a bulk flow cooler is applied instead of a fluidising cooler for product cooling, the power consumption can be reduced to 19 kWh/t as shown in Figure 9.

Improvement of product quality through a multi-spray nozzle

Smaller droplet size of sprayed urea solution on seed particles in the granulator by a spray nozzle has three major benefits. Firstly, smaller droplet size ensures greater surface area contact with spouting hot air at the spouting pipe. The efficient contact with air accelerates the vaporisation of water from particle. Secondly, smaller droplet size also improves the generation of more uniform and thinner film on the seed particle surface. This helps to realise the sphericity (roundness) of the product shape. Thirdly, smaller droplet size eliminates the agglomeration of product.

To achieve the benefits of smaller droplet size, TOYO has developed a multi-spray nozzle with four small nozzles (Figure 10) installed in the granulator. The multi-spray nozzle realises the smaller droplet size by a greater number of spray nozzles without increasing the size of the granulator and the number of spouting pipes.

The droplet size of the multi-spray nozzle has been confirmed by a water spray test and the results showed improvement for droplet size without atomising air compared to the conventional spray nozzles of full cone type with a single outlet hole. TOYO has confirmed the improvements in drying function and shape of product at actual plants as well, and, in recent projects, multi-spray nozzles have been applied.

Excellent emission control

Urea dust and ammonia are major subjects of emission control in urea plants. Guidelines prepared by the World Bank (International Finance Corporation of the World Bank Group) and the European Financial Management Association (EFMA) are summarised in Table 2.

As shown in Table 3, TOYO owns various schemes to treat exhaust air from the granulator containing urea dust and ammonia. All schemes apply a uniquely designed packed bed type low pressure loss dust scrubber, as shown in Figure 11. Some of the schemes have been applied in recent projects through profound discussion with owners considering worldwide standards or domestic environmental regulations.

Conclusion

This article has introduced the features of TOYO's ACES21 and spout-fluid bed urea granulation process. Excellent performance and reliability have been demonstrated in the successful commissioning of numerous plants, including the 4000 tpd IEFCL plant (Nigeria), which is the world's largest single train urea plant. WF

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THE FUTURE IS DIGITAL

Joerg Theis, ABB, Norway, explains the benefits that digital solutions can bring to the fertilizer industry.

The Food and Agriculture Organization (FAO) of the United Nations (UN) estimates that global demand for food will rise by 50% between 2012 and 2050 to feed a population of almost 10 billion. Furthermore, a rapid rate of urbanisation is expected in the coming years, with approximately 66% of the world's population expected to live in urban areas by 2050, compared to 54% in 2014.

The next 10 – 15 years will likely see rapid changes in the food system, driven by changing consumer demand, technological advances, trade dynamics and other factors. To achieve the UN Sustainable Development Goal number two, to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" by 2030, the FAO is calling for more productive, efficient, sustainable, inclusive, transparent, and resilient food systems.

Fertilizer is a key ingredient for the food business. By 2020, developing countries demand for cereals for direct human consumption is projected to increase by 47%. Half of all food grown around the world today, for both people and animals, is made possible through the use of fertilizers. As demand continues to grow, farmers

Figure 1. ABB power management system cabinet in E-House.

Figure 2. DCS collaboration arena control room.

around the world will continue to rely on fertilizers to increase production efficiency for producing more food while optimising inputs.

However, the reality of the fertilizer market today is weak demand and oversupply, with crop prices also low. Global fertilizer demand is expected to grow by an average of 1.6% per year over the next five years, according to the International Fertilizer Industry Association (IFA).[1] Meanwhile, structural overcapacity for urea, phosphoric acid and potash is expected. Global capacity growth of 12% is expected between 2016 and 2020, assuming that projects are realised as scheduled.

Opportunities to drive value

In order to produce high quality and competitive products that would meet the worldwide standards set by today's global market also seeking to reduce the operating costs, it is necessary to implement advanced, energy efficient technologies that fully satisfy environment protection requirements. The fertilizer industry is also accessing a growing menu of benefits from connectivity. Smart sensors, intelligent switchgears, distributed control systems and cloud computing are making it possible for fertilizer companies to exercise an unprecedented level of control. Data from every motor and automated process across an entire site can now be brought together in one control room, giving operators a complete picture of the health and performance of the facility.

As a multi-scope supplier, ABB is positioned to support and help customise integrated solutions for various fertilizer processes using customers' technologies, those of licensors or engineering, procurement and construction (EPC) contractors. ABB leverages its expertise to supply automation and electrical equipment for the manufacturing of plant nutrition and protection products, such as: nitrogen fertilizers, phosphate fertilizers, potash fertilizers, multi-nutrient fertilizers, crop protection, etc. ABB's integrated power and automation solutions can help to improve efficiency, safety and reliability while reducing OPEX and emissions.

Based in Finland, Kemira GrowHow Oy is one of Europe's leading producers of fertilizers and animal feed phosphates. Kemira GrowHow's Uusikaupunki plant in Finland produces industrial chemicals and fertilizers. ABB drives installed here cut the plant's energy bill by 4000 MWh annually. The new motors and drives permits savings of more than 4000 MWh a year. This equates to US$185 000 or 2800 t of CO_2.

ABB also supplied Fauji Fertilizer Bin Qasim Ltd (FFBL) in Pakistan with complete engineering, installation, supervision, testing and commissioning of the 800xA distributed control system for boiler control, balance of plant (BOP), power management system and electrical equipment monitoring. This new collaborative process automation system from ABB has enabled the customer to have the complete process and electrical system on a single platform to have better control and monitoring of their new 118 MW coal power plant that supplies power as well as steam to the existing fertilizer complex ensuring the highest level of system availability.

Figure 3. MNS-MCC.

Additionally, equipment damage can be minimised, power restoration can occur quicker, and lives may even be saved with UFES (Ultra-Fast earth switch and REA based Arc protection system) for medium-voltage switchgear.

As part of its 'Next Level Strategy', ABB is committed to work with its customers to continuously improve their productivity through the application of intelligent solutions realising the benefits of digitalisation – ABB Ability^{TM}, ABB's digital solution to the market. By bringing together all of its digital products and services into one interoperable end-to-end platform that leverages Microsoft's Azure cloud solution, ABB is expanding the business value generated for its customers.

This is exactly what ABB is doing for Yara, the leading global fertilizer company in Porsgrunn, Norway. ABB's intelligent low voltage switchgear is used to upgrade a production plant of Yara. Communications protocols are embedded within the MNS® low voltage intelligent switchgear optimising electrical distribution performance and condition-based monitoring while providing detailed process and electrical information to plant operators in real time. The switchgear will also increase electrical safety, support the reliable distribution of power, improve control and facilitate more efficient operation of a plant with more than 6000 electric motors.

One last example that will be helpful in painting a picture of the comprehensive technological impact on the fertilizer industry is analytics, which can be used across the entire value chain to improve operations. One major arena for analytics is precision agriculture, which involves collecting and analysing information at the individual plant level for improved agricultural practices. Remote sensing can help reveal patterns that can highlight problems and other information that may not be easily available. The flow of information is enhanced via centralised digital platforms that connect various stakeholders across the value chain. By improving the volume, quality, flow, and frequency of information used in manufacturing and other value chain stages, fertilizer production can become more efficient, productive, and sustainable. Several companies are expanding the use of analytics that helps make better and informed operating and financial decisions.

And beyond

There are also opportunities for deeper levels of analytics, with advancement such as artificial intelligence, which can help achieve improvements. This is a fast-reaching approach that will make the Fourth Industrial Revolution a real phenomenon with a global impact on productivity and incomes. In spite of the widespread interest in these developments, it may not be clear to everyone yet just how important digitalisation is ultimately going to be. In fact, we are on the cusp of a genuine revolution. Those who have the foresight to invest in it now will be poised to reap outsized returns. WF

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know your steam reformer

Diana Tudorache and Marie Basin, France, and Dieter Ulber, Germany, Air Liquide, look at state-of-the-art solutions for optimising reformer performance.

While optimising operations towards minimum production cost at maximum plant availability and reliability, the operators of steam methane reforming (SMR) furnaces typically face a number of challenges, including the following:

- Process analytics and optimisation of operating parameters.
- Catalyst tube monitoring during operation.
- Control of the SMR combustion system and the heat distribution inside of the firebox.

In order to better meet the needs of the customers, more than 30 researchers, reformer operators and engineering teams jointly work within Air Liquide to develop innovative technologies and solutions to continuously improve the efficiency and reliability of the more than 85 SMR units operated by Air Liquide worldwide, producing more than 2 million Nm^3/hr of hydrogen.

The state-of-the-art solutions and tools for plant optimisation developed and first deployed at Air Liquide plants are now available to other SMR operating companies, and will enable them to do the following:

- Perform plant energy audits.
- Implement accurate, reliable and reproducible tube temperature monitoring.
- Resolve heat distribution issues by minimising the temperature spread inside the SMR firebox.

Plant energy audits

Getting reliable plant data is at the heart of the challenge of plant operation and optimisation. Data reconciliation is a powerful technique that has been used for the past two decades to establish accurate plant heat and mass balances. At the same time, it is widely acknowledged that process measurements may not be 100% accurate.

Methodology

Air Liquide developed a methodology using an equation-based commercial software (Belsim Vali®). This tool uses information redundancy, conservation laws and thermodynamic principles to correct raw measurements and convert them into accurate and reliable information. The statistically corrected (reconciled) measurements and estimates are consistent with respect to the mass and energy balances of the considered process.

The first step of the methodology consists of evaluating the plant heat losses, which are relevant for the heat balance and may open ways for savings by adding additional insulation in key areas. The second step is building a dedicated model of the plant including all the sensors from the P&IDs. Finally, the last step before reconciling plant data is to evaluate the sensors' accuracy.

The outcomes of data reconciliation are as follows:

- Reliable and accurate plant balances.
- Key performance indicators computation with their uncertainty.
- Access to non-directly measurable parameters (e.g. PSA yield, catalyst activity, etc.).

This is the basis for further plant optimisation as described hereafter.

Case study: gains achieved on a 130 000 Nm^3/hr plant

A 130 000 Nm^3/hr H_2 plant was the first candidate to deploy data reconciliation a few years ago. The benefits of the study were twofold:

- Achieving an accurate plant performance evaluation.
- Highlighting potential for efficiency improvement.

The key performance indicator for SMR plants within Air Liquide is the thermal efficiency indicator (TEI), which measures the overall energy export over the energy consumption of the plant. Computing this indicator with

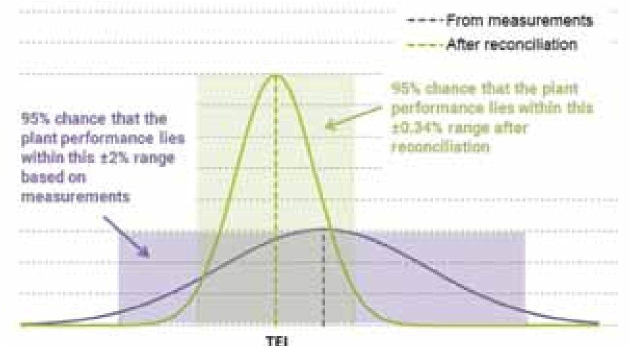

Figure 1. Plant thermal efficiency indicator range before and after data reconciliation.

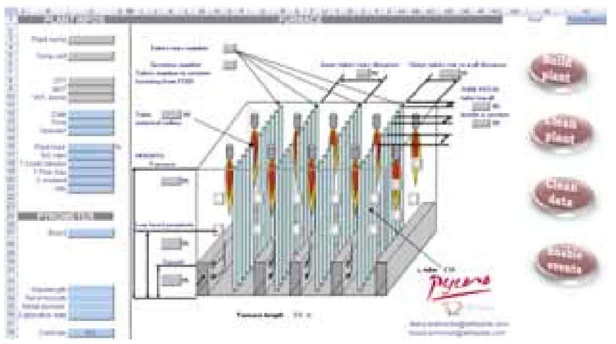

Figure 2. PYCOSO interface.

accuracy is crucial to evaluate plant performance and compare them with expected or design performances. A manual calculation done with process measurements and their accuracy landed a TEI with an accuracy of ±2%. The range of statistically probable values was so wide that it was not possible to conclude if the expected performance was met or not. Data reconciliation helped to improve this accuracy, reaching a high precision of ±0.34%. This is shown in Figure 1.

Based on accurate plant data obtained, the plant operation can be optimised. Data reconciliation computes key data, which allows for cost-saving adjustments without further investment. The findings for this case study were as follows:

- The steam to carbon (S/C) ratio was found slightly higher than its displayed value in the distributed control system (DCS). This provided an opportunity to optimise the performances and manage the risks of a low S/C ratio. A decrease of S/C as low as 0.1 would mean €100 000/yr savings for the plant.
- The flue gas temperature at stack was found higher than measured. More heat could then be recovered for preheating. A change in heat exchangers' operating set points could yield up to €130 000/yr.

This technique has been employed at numerous large SMR plants operated by Air Liquide.

Reliable and reproducible tube temperature monitoring

To get the best performance and highest reliability of steam methane reformers, an accurate, reliable and reproducible measurement of the SMR catalyst tube skin temperature is of major importance in order to detect hot tubes and to avoid excess design temperatures during operation. The availability of such data allows the operator to do the following:

- Operate the SMR unit at the highest possible SMR tube temperature, leading to maximum efficiency.
- Avoid exceeding the design limits of the SMR catalyst tubes, which can lead to major equipment failure in a short period of time.

Another tool, PYCOSO (Pyrometric Correction Software), provides accuracy to pyrometry measurements, which are subject to various uncertainties and complex specific corrections. Pyrometry is based on the measurement of radiation at a specific wavelength range that is converted by a detector into a temperature value.

When pointing out a SMR catalyst tube, the pyrometer receives the radiative flux leaving the tube surface, both emitted by the tube, but also reflected from the surrounding walls.

PYCOSO calculates the correction that must be done to retrieve the actual temperature of the tubes from:

- Tube temperature direct measurements.
- Wall temperature direct measurements.
- The exposition of the measured tube to the nearby walls.

Otherwise, as the walls are hotter than the tubes, the actual tube temperature may be overestimated up to 20°C. A tube facing a high temperature wall will have a higher correction than a tube situated in the middle of the furnace.

PYCOSO is a plant-universal tool with a user-friendly interface shown in Figure 2. It was successfully deployed to numerous Air Liquide SMR plants worldwide.

Implementation and benefits

The tool provides more accurate tube temperature values, leading to maximum operating margins. An example is given in Figure 3, showing the tube temperature distribution in a large SMR plant operated at nominal load. Measurements evidenced several tubes with raw temperature values exceeding the maximum operating temperature. Nevertheless, the more reliable PYCOSO corrected temperatures were all below SMR catalyst tubes' design temperature limit and thus the plant could be operated at nominal load or higher.

Mitigation of tube temperature spread in an SMR plant

For the safe and optimised operation of an SMR plant, the temperature difference between the hottest and the coldest SMR catalyst tubes is critical. This temperature difference is commonly called tube temperature spread, and it has to be reduced in order to operate the SMR furnace more efficiently. For large units, the spread can be up to 90°C. Such high temperature spreads provide significant potential for energy savings to the extent of several hundreds of thousands of euros per year.

Furthermore, high temperature spreads can limit the production capacity of the SMR unit, in case the design temperature of the SMR catalyst tubes is met for individual tubes before reaching full plant capacity.

As a result, finding mitigation strategies is of great interest for companies operating SMR plants.

An intuitive way to process is to adapt the power of each individual burner to homogenise the heat transfer to the reforming tubes. This strategy is called 'burner throttling' and has

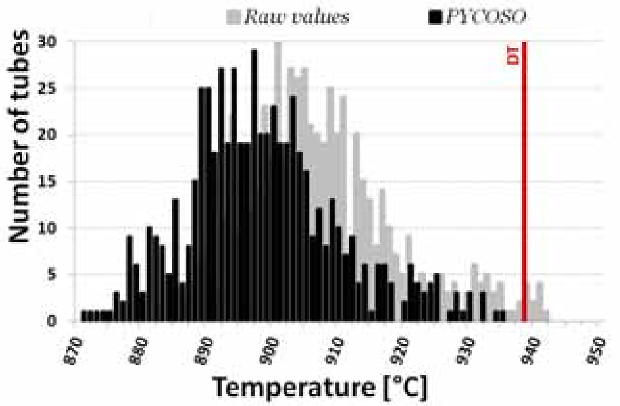

Figure 3. Tube temperature distribution in a large scale SMR plant. Comparison between raw values (in grey) and reflected luminance corrected values with PYCOSO (in black).

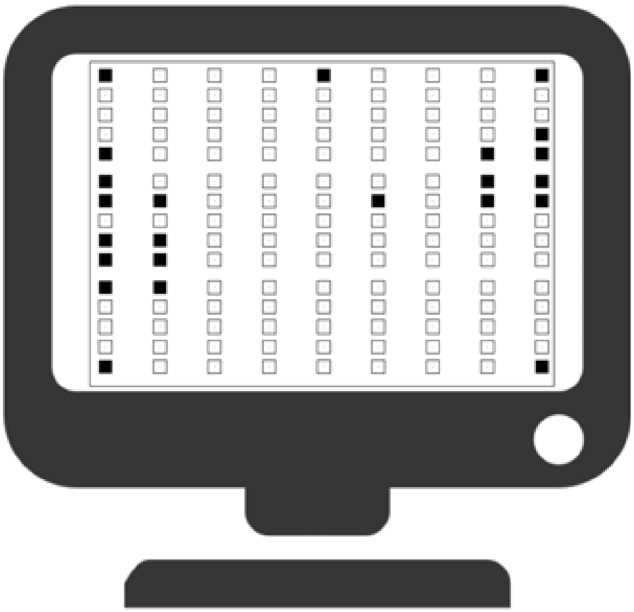

Figure 4. Example of throttled burners map with a single throttling condition (throttled burners are represented with full squares and non-throttled burners with empty squares).

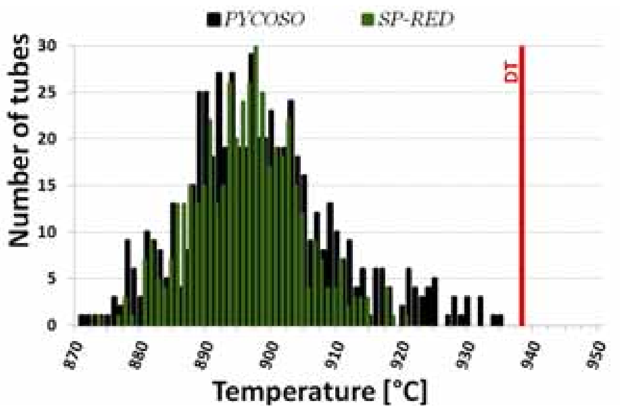

Figure 5. Tube temperature distribution in a large scale SMR plant. Comparison between PYCOSO values (in black) before throttling with SP-RED values after throttling 23 burners (in green).

two main advantages: it does not require a plant shutdown; and no additional device needs to be installed. In short, burner throttling does not imply any specific investment, but brings major savings. It is definitively a cost-effective technique. Though the method is simple in principle, finding the right burners that need to be throttled may be tricky and time consuming in practice, especially for large furnaces with dozens of burners. That is why Air Liquide developed SP-RED (Spread Reduction tool) – a tool based on an in-house mathematical model and optimiser capable of determining the burners that need to be throttled in less than 10 minutes. The method includes the following three steps:

- Firstly, measuring temperatures of the reforming tubes under non-throttled conditions by a pyrometer. It is mandatory to correct the measurements with PYCOSO to accurately capture the tube temperature profile.
- The second step consists of running the SP-RED algorithm with the tube temperatures measured on site as input and thus getting a SMR-specific burner throttling map (Figure 4).
- Finally, throttle the burners on site thanks to the map generated by SP-RED.

Several burners' throttling conditions can be implemented thanks to SP-RED, which means that the burners can have different percentages of power reduction. Figure 4 shows an example of a burner throttling map with burners throttled by the same power rate of 40%. To mitigate the tube temperature spread, SP-RED estimates that the power of the 23 burners highlighted by black squares must be reduced by 40% with respect to the baseline burners shown in empty squares.

Benefits of implementation: an example

SP-RED methodology was implemented in a 135-burner furnace. The tube temperatures of this furnace under non-throttling conditions are shown in Figure 5, as well as the temperature profile after throttling 23 burners identified by SP-RED optimiser, pointing out a significant spread reduction. In addition, once implemented, SP-RED will allow the plant debottlenecking as the hottest tube backs away from the design temperature limit.

The SP-RED methodology was further implemented in other furnaces with successful spread reductions of approximately 25°C.

Conclusions

Modelling and numerical tools are essential to improve the efficiency of reformers by unlocking key optimisation parameters:

- A good level of process information with higher accuracy can be achieved despite poor instrumentation thanks to data reconciliation.
- Tube temperature measurements with higher accuracy are provided, enabling the reformer to be operated close to the design temperature limit.
- Burners that required power reduction can be evidenced and adjusted accordingly by linking PYCOSO temperature profile to SP-RED optimiser, thus mitigating the heat transfer to the reforming tubes.

This set of tools helps reformer operators to make decisions in their day-to-day work. WF

IMPROVING THE PROCESS

Pallavi Baddam, Mitsubishi Heavy Industries Compressor International, USA,
discusses how upgrading and revamping syngas turbines in existing ammonia plants can increase capacity and improve the process.

Ammonia is the most important and basic building block of the fertilizer industry. The industrial method for ammonia synthesis is the Haber-Bosch process, invented by Fritz Haber in the early 1900s and developed for the industry by Carl Bosch in 1913. This process synthesises ammonia from molecular nitrogen and hydrogen by feeding the reactants over iron catalysts at high temperature and pressure. The synthesis gas (syngas) needs to be compressed to high pressures, ranging from 100 to 250 bar, for ammonia synthesis. To achieve this, modern plants employ centrifugal compressors, which are usually driven by steam turbines that use the steam produced from excess process heat. Synthesis gas compressors driven by steam turbines play an important role in the ammonia plant. They are specially designed to cope with high speeds (exceeding 10 000 rpm) and high output powers (up to 45 000 KW).

The total world production of ammonia is estimated to be approximately 146 – 160 million t. The world's largest plants produce approximately 3000 tpd. On a recent project, Mitsubishi Heavy Industries Compressor Corp. (MCO) supplied syngas turbines to the world's largest ammonia plants (3300 tpd). While the ammonia prices continue to have an upward trend due to lower supplies in regions such as Black Sea, its demand tends to increase continuously. Therefore, it is expected that the demand for ammonia will increase to nearly 200 million t in 2018 and there are plans to build plants that can produce 4000 – 5000 tpd. Hence, the design

Figure 1. The existing syngas turbine casing in a customer's plant (Russia) before modernisation.

Figure 2. Additional unknown screw inside turbine casing.

Figure 3. No serration on the flange.

capacity of these ammonia plants have increased significantly in the past few decades.

Building new ammonia plants can be quite an undertaking due to its complex processes and high CAPEX. Therefore, the operators of ammonia plants are always exploring ways to increase the production capacity. Most of the operators are keen on increasing their production capabilities by upgrading their existing plants. This approach not only helps the operators to stay competitive, but also produce ammonia in cost-effective and energy efficient ways. Recent studies show that the debottlenecking projects for ammonia plants after 30 – 40 years operation within Europe and former Soviet Union (FSU) regions have become increasingly common. The process licensors are also making significant strides in modifying their original processes to achieve this goal. While numerous strides are made for improvements in increasing capacity, improving the processes, etc., this article introduces MHI's experience in upgrading/revamping syngas turbines in existing plants.

Case study 1: reduction in overall steam consumption by replacing internals

A customer in Russia has been operating a 30 year old syngas turbine in an ammonia plant. The efficiency of the steam turbine deteriorated over time due to various reasons and, as a result, steam consumption increased. Therefore, the customer requested that the steam consumption was reduced.

The present condition and turbine history was analysed. It was concluded that steam reduction could be achieved by replacing the turbine internals without replacing the casing. Upgrading the internal components shown in Figure 1, such as the rotor, diaphragms, nozzles and labyrinths, helped improve the overall efficiency of the syngas steam turbine.

From analysis of the turbine operating history, it was found that the syngas turbine was operating with a conventional nozzle and blade design, which is relatively older technology. In the case of conventional nozzles and blades, the first stage of speed control accounts for a large part of total loss, i.e. tip leaking loss, frictional loss, nozzle and blade losses related to their profiles, etc. Due to these losses, stage efficiency is reduced. In order to increase the efficiency, the conventional nozzle and blade have to be improved and optimised in order to reduce the above mentioned losses. As a result, several modifications, such as gauging optimisation, pitch and cord optimisation, profile modifications, etc., were performed on the nozzle and blade design. These modifications helped improve efficiency by minimising the losses. Integral shroud blades (ISBs) were also developed. ISBs can enhance blade rigidity by forming grouped structure for higher profile performance with small gauging. ISBs also do not have tenon caulking as the shroud is integrated with the blade. The stage efficiency was increased by using a combination of a new nozzle and the integral shrouded blade design.

In addition to this, slant labyrinths were used for high pressure side and extraction portion. This helped decrease the seal leakgage and improve the efficiency. The performance of the syngas turbine was evaluated before and after revamp, as shown in Table 1. The data was collected over a period of two days of operation. It was found that the steam consumption was reduced by 15% as a result of increasing the efficiency of the steam turbine.

Case study 2: repairing the existing turbine casing and replacing internals

The same customer also had a spare synthesis gas turbine manufactured by MCO. A portion of the existing turbine

Figure 4. Damaged baffle plate.

Figure 5. Cut piping.

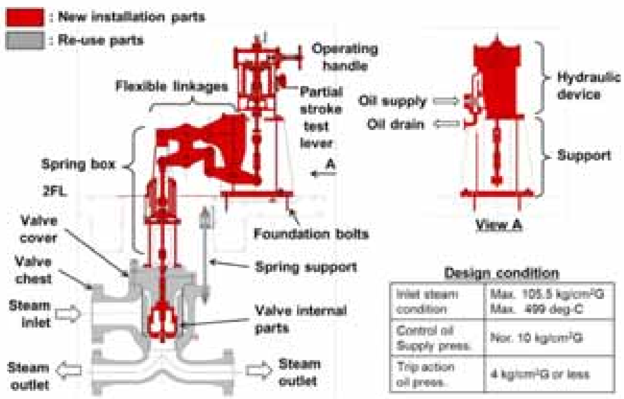

Figure 6. Modernised hydraulic trip and throttle valve (TTV).

casing had been modified by another original equipment manufacturer (OEM). A comprehensive survey/investigation was conducted to document the present state of the equipment, where it was found that the existing spare unit could be restored by using modernisation techniques involving installation of a new turbine rotor and internal parts. The existing turbine casing was then shipped to MCO's factory in Hiroshima, Japan. Figure 2 shows the existing turbine casing pictured in the customer's plant prior to restoration.

Step 1: inspection of the existing turbine casing

In order to re-use the existing turbine casing, MCO measured important dimensions, such as flatness of the horizontal surface of the casing, contact surfaces to internal parts, and each screw position. These measurements were then compared with the original drawings. The purpose of the inspection was to check the distortion of the horizontal surface, as well as the parts on the casing that have been modified. Flatness measurements were taken.

The discrepancies from the measured values to the values on the original drawings were captured and analysed. Figures 2 – 5 show distortion and damaged parts, such as additional machining within the casing and unknown screws and piping. An additional inner casing was installed to the existing turbine to match the other OEM's design. The other OEM's design philosophy was completely different to MCO's. An additional inner casing was not required for MCO's design and proved futile. Oversized screw machining was performed for unknown screws and a new plug was welded and installed.

Figure 3 showed no serration on the flanges. Longer periods of operation wore the serration, leading to leakage. Therefore, new flanges were installed.

Figure 4 shows a deformed baffle plate due to operation, which was installed between the turbine casing and bearing pedestal. The deformed baffle plate was removed and a new baffle plate was installed.

Figure 5 shows cut piping. This piping leads to the gland sealing within the turbine. This was cut due to unknown reasons. New piping and flanges were installed to ensure the gland sealing system works as desired.

Step 2: repairing the existing turbine casing

The damages found as a result of a flatness inspection discussed above (Figures 2 – 5) were repaired to increase performance. The turbine casing was repainted after NDT testing and the horizontal surface was machined within the acceptable tolerance for new turbines. A hydrostatic test was performed for the repaired casing applying the same pressure as stated per the original casing technical specification in order to check that there was no leakage.

Additional damages found were repaired by manufacturing new parts, cutting and re-welding the existing parts as required. In addition to the casing repair, the new turbine rotor manufactured was tested, inspected and installed.

Table 1. Turbine performance evaluation results

Operating condition	Inlet steam consumption (tph)		Steam consumption reduction (tph)
	After revamp	Before revamp	
Guarantee base condition	320.3	335.4	15.1 ↓

External (auxiliary) modifications – hydraulic trip and throttle valve

The trip and throttle valve (TTV) plays a very important role in steam turbine operation. The main function of the TTV is to stop turbine operation safely in the event of an emergency shutdown. The original TTV design was mechanically operated and lacked smooth control due to heavy structural design. Long-term operations caused sticktion at the TTV stem due to accumulated dust from the outside environment, causing the TTV to be dysfunctional after longer periods of operation.

Figures 6 and 7 show the modernised hydraulic TTV. This upgrade involves revamping an existing mechanically operated TTV to operate hydraulically by adding new installation parts, shown in red. This modification allows the existing valve body and cover to be reused. This feature allows a customer to upgrade to a hydraulically operated valve with minimal part changes and reduce onsite work. The valve and hydraulic parts can be overhauled separately for ease of installation and maintenance. The main advantages for this upgrade are a smooth valve operation by hydraulic force and the ease of conducting online checks for sticktion by 'partial stroke test device'. In addition to the above, there is no possibility of fire by unexpected oil leakage, because the hydraulic portion is located separately from the hot TTV body.

Figure 7. 3D model for modernised TTV.

Conclusions

Revamping or modernising the existing syngas turbine and auxiliary parts in a plant can sometimes prove to be cost-effective in lieu of replacing it with a newer one. However, this type of initiative has to be carefully reviewed jointly by the operator and the OEM in order to completely understand the merits and demerits. The OEM would have to carefully consider the original design tolerances, operating philosophy and required guarantees prior to performing an upgrade. Utilising the existing footprint and modifying the equipment in order to improve efficiency is feasible provided an OEM has extensive experience in doing so. MCO carefully compares the merit of these upgrade/footprint replacement initiatives with new units and provides a detailed study report that enables the operator to make decisions that ensure cost benefits. **WF**

North America

15 FACTS

If fertilizer use was to stop, agricultural output in North America would be reduced by approximately 30%

Nutrien controls the majority of North America's potash capacity

North America consumes 15.5% of the world's potash

New York and Los Angeles are the only cities in the US to have at least two teams competing in each of the four major sports leagues

The Canadian Lac à Paul project is one of the largest greenfield phosphate projects in the world

The Chihuahua is the world's smallest dog and is named after a Mexican state

The word 'America' comes from the name of the Italian explorer Amerigo Vespucci

There are 23 countries within North America

The current Canadian flag was first introduced in 1965

Canada is the world's largest producer and exporter of potash

The US is the most successful nation in the Summer Olympic Games and the second most successful in the Winter Olympic Games

The world's largest pyramid is in Mexico, not Egypt

Alaska was purchased from the Russian Empire in 1867 for US$7.2 million

The US Government owns GPS, and can 'switch it off' at any point

North America has a population of approximately 579 million people